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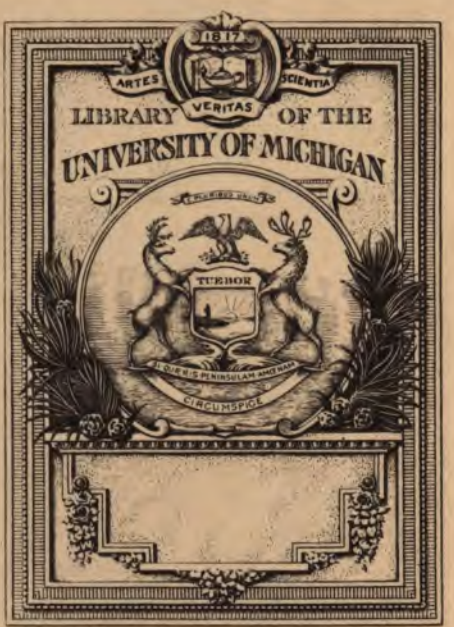
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SECOND TREATISE

ON THE

DECREASE OF WATER

IN

SPRINGS, CREEKS, AND RIVERS,

CONTEMPORANEOUSLY WITH

AN INCREASE IN HEIGHT OF FLOODS IN CULTIVATED COUNTRIES,

BY

SIR GUSTAV WEX,

IMPERIAL AND ROYAL MINISTERIAL COUNSELLOR AND CHIEF ENGINEER
OF THE IMPROVEMENT OF THE DANUBE, AT VIENNA,

WITH SIX SHEETS OF DRAWINGS

FROM THE PAPERS OF THE SOCIETY OF THE AUSTRIAN ENGINEERS
AND ARCHITECTS, 1879—Nos. 6-9.

TRANSLATED BY

G. WEITZEL,
Major of Engineers, Brevet Maj. Gen. U. S. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1880.

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SECOND TREATISE

ON THE

DECREASE OF WATER IN SPRINGS, CREEKS, AND RIVERS.

OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, D. C., July 1, 1880.

SIR: An interesting paper on hydraulic engineering entitled "Zweite Abhandlung über die Wasserabnahme in den Quellen, Flüssen and Strömen bei gleichzeitiger Steigerung der Hochwässer in den Culturländern" (Second treatise on the decrease of water in springs, creeks, and rivers, contemporaneously with an increase in height of floods in cultivated countries), by Sir Gustav Wex, imperial and royal ministerial counsellor and chief engineer of the improvement of the Danube at Vienna, has recently been translated, at my request, by Bvt. Maj. Gen. G. Weitzel, United States Army.

As this paper contains information of value to the officers of the Corps, I have the honor to recommend that it be printed, for the use of the Engineer Department, at the Government Printing Office, and that 500 copies be furnished on the usual requisition.

Very respectfully, your obedient servant,

H. G. WRIGHT,
Chief of Engineers, Brig. & Bvt. Maj. Gen.

Hon. ALEXANDER RAMSEY,
Secretary of War.

Approved:
By order of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

JULY 6, 1880.

VIENNA, *October* 12, 1879.

GENERAL: I take the liberty of transmitting to you in the accompanying package my second treatise, entitled "On the decrease of water in springs, rivers, and streams, simultaneous with the increase of floods in *cultivated countries*," because I am convinced that such a distinguished *hydraulic engineer* will take a lively interest in the definite solution of

a hydraulic question, which is of the highest importance to coming generations and future condition of cultivated countries.

At the same time you will please have the kindness to accept this copy as a mark of my most eminent esteem.

Finally, I take the liberty of politely begging you to transmit for use the other copy of my treatise which accompanies this to the esteemed societies of engineers which exist in your country, with the request that they may thoroughly examine my theory with regard to the decrease in water supply, and illustrate it more clearly by the publication of the hydraulic observations made on American rivers and streams.

With the assurance of my highest esteem, I remain your devoted

SIR GUSTAV WEX,
Imperial and Royal Counsellor.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, Washington.

INTRODUCTION.

In my first treatise bearing the foregoing title, published in the papers of the Society of Austrian Engineers and Architects, 1873, after observing gauges during many years at nine different stations on the five main rivers of Central Europe, viz, the Danube, Rhine, Elba, Vistula, and Oder, and also after many other observed results, I furnished the proofs that the discharge has diminished considerably during the latter decade, not only in the above-mentioned rivers themselves, but also in their tributary rivers, creeks, and springs.

In that treatise I also thoroughly discussed the causes of this peculiar hydraulic phenomenon, and finally proposed measures and precautions to prevent as far as possible the further spread of this calamity, so threatening to future generations.

Since the publication of that treatise, this hydraulic question thus raised by me has been industriously studied in nearly all countries, partly by scientific institutes and partly by individual naturalists and experts, and their various opinions and views have been published.

In by far the greater number of the opinions which have thus appeared some of these scientific institutions and authors have entirely, and others only partially, agreed with my views, conclusions, and the theory which I recommend, and, at the same time, have brought forward many new illustrations and arguments to establish its correctness.

But especially, as several engineers and hydraulic experts have expressed the opinion that my conclusions as to the decrease in the height of water in rivers are unreliable, and that the remaining proofs for the decrease in discharge are not quite unassailable, and, besides, because several of these experts have even advanced the new theory that the established decrease in the height of the water is not in consequence of the decreased discharge, but rather due to changes in and particularly to the deepening of the river beds, I have during six years shunned neither labor nor expense in obtaining as many and reliable technical hydraulic measurements and data as possible of different streams, so that I might clearly ascertain whether the views previously expressed by me or those of my opponents were more nearly correct.

Now that I have in the course of these uninterrupted and continued collections of data and studies, and even by the latest of these, arrived at the fullest conviction that the theory advanced by me relative to the decrease in the discharge of springs, rivers, and streams has been unfortunately proven true, I feel myself impelled to publish this second treatise, since I believe that an indisputably clear exposition of this water question is not only of great importance in technical hydraulics, but also in its bearing upon questions in natural science and history of culture, as I have already pointed out in more detail in my first treatise. But a general knowledge of the decrease in discharge of springs and rivers and *the resulting* highly detrimental consequences for the future *cultivation of countries* and their inhabitants is absolutely necessary,

for then alone it can be hoped that the general governments, corporations, large land-owners, and individual communities will take suitable precautions and measures to confine the calamity to such limits as are yet feasible.

In Chapter I of this treatise I shall present, very briefly, the opinions given on the question by scientific institutes first, and then those of the individual naturalists and experts who agree with me; and subsequently, in Chapter II, with the latest data collected by me as a basis, will furnish the proof that the objections made by my opponents, and the new theories established by them, are either groundless or are based upon incorrect premises.

CHAPTER I.

1. The Imperial Academy of Sciences in Vienna, at my request, appointed from its own members a commission of five experts to give a formal opinion upon my treatise, which commission, after a thorough examination, in their report dated April 23, 1874, declared themselves in general as agreeing with me in my proofs and conclusions, and only remarked that my conjectures that the rainfall in cultivated countries must now have equally decreased, as not sustained by the meteorological observations made in England, Scotland, and at Paris during a period of many years, and although it would be hasty to conclude from this that no such changes have taken place in the interior of the continent, yet the measurements of rainfall at the continental stations (which, however, do not reach so far back) are not favorable to such an assumption.

The Imperial Academy of Sciences at its anniversary meeting of May 30, 1874, accepted the above-mentioned report of its commission, and resolved at the same time:

(*a*) To call the attention of the Imperial and Royal government to the continued decrease of discharge in springs and streams, as well as to the causes of the phenomenon, and at the same time to apply to the higher ministries, so that the measures and precautions proposed by Wex to prevent, as far as feasible, the further spread of this calamity may be thoroughly considered and carried into execution by the enactment of suitable laws.

(*b*) To send a copy of Wex's treatise to the scientific institutes of foreign countries with the request that they furnish the Imperial Academy with the results of observations extending through a series of years of the gauges in their rivers, and to furnish this information arranged and plotted in a manner similar to that adopted in his treatise.

(*c*) To express, also, to the Austrian Government the desire that stations may be erected at suitable points on several rivers, not only to observe the stages, but also to measure the discharge, in order to examine more closely the laws of dependence of the latter on the former.

For these resolutions, which were prepared by the Imperial Academy and carried into execution, I must before proceeding further return my sincere and grateful thanks to it, for thereby the scientific societies in other countries were incited to cause accurate observations and study of this important water question to be made.

2 and 3. As a result of this the Imperial and Royal Academies of Sciences of St. Petersburg and Copenhagen appointed their own commissions to examine my before-mentioned treatise, which in their reports *on this subject,* dated respectively January 22, 1876, and October 7, *1875, declare themselves* as generally agreeing with me in my views and

conclusions, but at the same time remark that a diminution in the rainfall was not established for those localities by the meteorological observations taken through a long series of years. The St. Petersburg commission added, however, to its opinion "that it might, nevertheless, be possible that a difference in distribution of the rainfall and of the evaporation from the surface of the earth might cause a decrease in the total amount of water in some and an increase of the same in other rivers."

The same commission, referring to their observations on the results of clearing lands, also mentions that in the southern parts of Russia, where notoriously one hundred and fifty or two hundred years ago there still existed large wooded tracts, at the present time bleak steppes have developed themselves, whose elevated portions are entirely destitute of water, and whose inhabitants are compelled, therefore, to settle on the banks of the meager and deficient rivulets in order not to perish from want of water.

The same commission still further adds that on the Lower Volga and Dnieper the neighborhood is cleared, and that in consequence the river beds fill with sand-bars, change, and become shallower, but that the floods rise higher than formerly.

The commission of Copenhagen expresses in its reports the following noteworthy opinions:

"Since in the later times our forests have not undergone any change, it is difficult to substantiate the gradual decrease of water in consequence of clearings, but we must nevertheless add that everything leads to the conclusion that at the time when Denmark was covered with large forests, the volume of water in our rivers must have been far greater than it is now, for there are many rivers in the country which exhibit traces of having had at one time a considerable discharge, but now have only a very small one or none at all.

"That the change of woods into cultivated fields has caused a considerable decrease in the volume of water in Danish rivers, the commission can prove as an indisputable fact by the lakes near Copenhagen.

"These lakes are situated in an extensive and flat country, the soil of which consists of clay overlying a stratum of chalk. This entire plain was once a forest, which has gradually partially disappeared, so that some of these lakes are now found in the open fields, and the others in the woods.

"The observations which were made have now established that those lakes which are situated in or near woods receive a much greater volume of water than those of the same area which are situated in cleared country, and as the other circumstances are precisely the same one must conclude that the decrease in the volume of water in the latter is to be ascribed to the clearing of the woods."

The Danish commission finally expressed its opinion "That the destruction of forests results in a considerable decrease in the discharge of rivers, and particularly in that of springs, and, furthermore, that the increased cultivation of fields, and also their artificial irrigation, cause a still greater decrease in the volume of water in springs and rivers."

4. The Royal Board of Canal Directors in Norway intrusted Lieut. Hans Nysom with the task of collecting the data desired by the Imperial Academy of Sciences of Vienna, who, in compliance therewith, in his report dated May 20, 1877, shows that at the two water-gauge stations at Nastangen and Sarpfos, on the Glommen River, which have until *now not been affected* by any improvement of the river, the observa- *tions taken during thirty* years confirm the theory of Mr. Wex in regard

to decrease in the volume of water in rivers, as well as his opinion of the causes of this phenomenon.

5. At my request the Society of Austrian Engineers and Architects also appointed a committee of experts to give an opinion on my treatise, which, in its report on this subject, made April 17, 1875, expressed the following opinions, viz:

(*a*) The committee recognizes the vast importance of the question raised by Mr. Wex, but, at the same time, the difficulties of a reliable reply thereto from the observations and data which so far have been laid before it.

(*b*) In the opinion of the committee it cannot safely be concluded that because there is a decrease in the mean stage there is a decrease in the discharge of a river, because if there should be a change in the cross-section of discharge, or in the slope of the river, the gauges are no longer reliable, and that it is, therefore, absolutely necessary that accurate and regular hydraulic measurements be taken at a number of constant cross-sections on the main river and its tributaries.

(*c*) Although the accurate measure of decrease in volume of water, expressed in figures, cannot be determined from the data furnished by Court Counselor Wex, yet they point to the fact that in the rivers mentioned there has been a decrease in the volume of water.

(*d*) The data furnished in the treatise show clearly the fact, of so much greater importance to the engineer, that the regimen of the rivers mentioned has lately undergone a considerable change.

(*e*) The causes mentioned by Wex of the hydraulic changes under discussion were partly combated and partly doubted in several respects, and particularly the assertion that in cultivated countries the rainfall has diminished by reason of the clearings; but it was admitted that the clearings had exercised a very injurious influence on the regimen of rivers.

The Society of Austrian Engineers and Architects adopted the above resolutions of its committee of experts at its business meeting on April 17, 1875, and authorized its executive committee to submit the amended conclusions of the Court Counselor, Wex, to the Imperial Royal Austrian Government, with the request for their execution, in order to limit the threatening calamity as much as possible.

6. At the International Congress of Agriculturists and Foresters at Vienna, in September, 1873, the royal Prussian inspector of forests, Dr. A. Bernhardt, related, and then the royal Italian senator, Louis Torelli, of Rome, submitted, very interesting data concerning the results of clearings in Europe, and proved thereby that many springs fail; that the discharge of creeks and rivers at a normal stage decreases more and more; and that on the other hand floods now occur oftener and rise to a greater height.

7. Mr. Torelli, particularly in his work* published May 10, 1873, furnishes data worthy of notice, gathered from the copious hydraulic observations and notes taken in Italy, showing the injurious effects of clearings in that country, and gives the following opinion, based upon abundant examples and experiences, viz:

"However great may be the evils and disadvantages of the more frequently and higher rising floods of the present time, they are not greater than those which result from the progressive failing of springs and decrease of volume of water in creeks and rivers."

* "*Delle cause* principali delle piene dei Fiumi e di alcuni provvedimenti," per diminuirle *di Luigi Torelli, Senator del* Regno. (The principal causes of high waters and *some measures for diminishing* them, by Louis Torelli, senator of the kingdom.)

Mr. Torelli further cites the following observations and measurements of the distinguished expert, Paleocapa, viz:

The volume of water at the lowest stage of the river Sele has decreased 33 per cent. during the last 150 years; that of the river Brenta, at Bassano, 7 per cent., between 1684 and 1877; and finally that of the river Adda, where it flows out of Lake Como, 13 per cent., between 1842 and 1862; and this decrease still continues, and therefore creates apprehension.

8. In consequence of the destructive inundation of the river Po, in 1872, the Royal Italian Government organized a commission consisting of seven experts, whose duty it was to make a minute hydraulic survey of its whole valley, and, after a thorough study thereof, to recommend such measures as would be suitable to prevent similar occurrences.

In the report made in December, 1876, by Mr. Basilari, vice-president of the supreme board of public works, the commission expressed the following opinion, viz:

The floods of the river Po have constantly increased in height, especially during the present century, in consequence of which it became necessary to raise and strengthen the greater portion of its levees. This method of relief was considered by the commission not only as inadequate, but as really increasing the danger, for which reason it was led to consider means by which the height of these floods could be diminished, or, at least. the increase stopped. Consequently it examined into the condition of the forests in the valley of the Po. It laid great weight on the enactment of suitable laws against destruction of forests; recommended next the construction of large reservoirs for the storage of a portion of the floods, which might subsequently be used for irrigation; further proposed the construction of suitable works for improving the mouths of its tributaries; and finally recommended several cut-offs, in order to diminish the length of the stream.

The preceding opinion and the proposed measures therefore fully coincide with the views expressed in my treatise of April, 1873.

9. Professor Dr. Ebermayer, in his admirable work entitled "Physikalische Einwirkungen des Waldes auf Luft und Boden und seine klimatologische und hygienische Bedentung begründet durch die Beobachtungen der forstlichmeteorologischen stationen in Königreich, Bayern. Aschaffenburg, 1873,"* has furnished convincing proof of the following statements, based upon minute scientific experiments and observations during many years, viz:

(*a*) The forest influences the amount of rainfall by increasing the relative humidity of the atmosphere and bringing it nearer the point of complete saturation, so that when the temperature is lowered a partial separation of the water takes place more easily and in greater quantity than in clearings. This influence is more marked in proportion to the height of the forest above the level of the sea.

(*b*) The forest diminishes the evaporation of the surface water in a much greater degree than an open field. In those whose grounds are kept clean it amounts to 62 per cent., and in the others to 68 per cent.

(*c*) In the interior of the continent, where the humidity of the atmosphere and annual rainfall decrease and the degrees of summer heat increase, the forest has a greater influence on the rainfall than in the coast regions. Ireland and Great Britain can dispense with their forests more easily, as far as rainfall is concerned, than Germany or Russia.

*The physical effect of the forest on the atmosphere and soil, and its climatological and hygienic importance, based upon observations made at the foresters' meteorological stations in the Kingdom of Bavaria. Aschaffenburg, 1873.

(*d*) Large clearings in level countries have material influence, it is true, but in hilly regions there will be, on an average, less rainfall than before, and especially in the warmer half of the year.

Even if it were assumed that, after clearing forests, under all circumstances, the rainfall would be the same as before, the enormous influence of the forest, and its ground covered with leaves and brush upon the evaporation of its surface water, in consequence of which, compared to the surrounding country, it must be considered a great reservoir, would sufficiently explain the well-known failing of springs and its influence in diminishing the medium stages of the rivers.

(*e*) There is another fixed relation between the stage of water in rivers and the forest caused by the fact that in wooded localities the snow lies three or four weeks longer and melts less rapidly than in clearings. In an open country the rise in rivers occurs more rapidly after the melting of the snow; the latter runs off more rapidly, less soaks into the ground, and the springs are therefore fed less than in wooded countries.

(*f*) Extensive clearings are more injurious in hilly than in level countries. They produce in a short time destructive torrents, dry periods, then short but destructive inundations, formation of sand-bars in rivers, want of perennial springs and creeks, and great variations in the stage of the rivers. These most certainly occur and characterize such regions in which the hills have been cleared.

Mr. Ebermayer says, finally, viz:

(*g*) "If we combine the different effects of the forests, there can be no doubt but that their disappearance must considerably diminish the volume of water in a country, even if after the clearing there is as much rainfall as before."

"The preceding statements show how closely the wealth of forests and water in a country are bound together; a circumstance which is particularly due to the powerful influence which the forest and its ground covered with leaves and brush has upon the evaporation of the moisture in the ground. It is, then, not to be wondered at that springs and creeks dry up or flow only periodically; that the mean stage of rivers and creeks diminishes in height when large clearings are made in a country, and that on the other hand springs flow more copiously and regularly when new trees are planted and forests are increased in extent."

10 and 11. The imperial chief forester, Edward Ney, of La Brogue, in Alsace, in a paper published in January, 1875, entitled "Ueber den Einfluss des Waldes auf die Bewohnbarkeit der Länder,"* and Dr. Jacob von Bebberer, in his paper published in 1877, entitled "Die Regenverhältnisse Deutschlands,"† both written after observations made during a long series of years, on the great influence of the permanence of forests on the hydraulic condition of countries, have expressed precisely the same opinions as Professor Ebermayer.

As an illustration of the fact that the clearing of hilly countries frequently results in the complete failing of springs, Mr. Ney mentions that in the Provence, after all the olive-trees, which there formed regular forests, had been frozen in 1822 and cut down, a great number of springs failed totally, and that besides, in the city of Orleans, after the surrounding heights had been thus cleared, nearly all the wells dried up, and it became necessary to conduct the headwaters of the river Little Loire into the city.

Mr. Ney furnishes the following examples to prove that during the

* "*Concerning the influence* of the forest on the habitableness of countries."
† "*The circumstances relating* to rain in Germany."

historical period many rivers once rich in water supply have become much poorer therein, notwithstanding their more frequent floods in consequence of the destruction of the forests, viz:

At the time of the Roman rule in France, the river Durance, south of Avignon, and the Seine were navigable rivers and richly supplied with water, so much so that the navigators of the Durance formed an influential corporation, and Emperor Julian, who resided in Paris during a period of six years, particularly extols the constant even stage of the Seine. At present, since the regions of the headwaters of these two rivers have been cleared, the Durance can hardly float a skiff in summer, and the Seine, in which the difference between the high and low water stage is now 32 feet 10 inches, was only made navigable again by the construction of numerous wing-dams.

12. The director of the royal board of foresters of Hanover, Dr. Burckhardt, in a letter addressed to me on March 5, 1876, says the views expressed by me in my treatise were expressed in words which were as if taken from his own soul, and that he had also, in the course of his observations extending through a period of twenty-five years, seen the sad results confirmed that in consequence of the clearings made in North Germany there resulted the disappearance of many lakes and ponds, draining of marshes, failing of many springs and creeks, and the lowering of the surface water, whereby the cultivation and productiveness of the remaining fields suffered sadly.

13. Prof. Alexander Bettochi, inspector of the Royal Corps of Civil Engineers at Rome, in his memoir submitted to the Royal Academy, "dei Lincei," in June, 1876, which was subsequently published as a paper, acknowledges that my theory relative to the diminution of water in springs and rivers contemporaneously with the increase in height of floods agreed with observed results, and still further substantiated it by plotted observations made on the Theiss at Szegedin.

14. Mr. Frederick Symong, imperial and royal professor of geography at the University of Vienna, honorably known by his researches and surveys in the Alpine regions, in his lecture entitled "Schutz dem Walde,"* given February 21, 1877, before the Society for the Diffusion of Knowledge of Natural Sciences, at Vienna, acknowledged my theory as being correct, and at the same time proved conclusively that in consequence of the destruction of the forests in mountainous regions the rainfall diminishes at those points, vegetation on the mountain sides is constantly receding, the soil is washed off, after which the mountains gradually become perfectly barren. A further result of this is a decrease of water in the lower strata, in springs, creeks, and rivers, which in turn are succeeded by the drying up of the valleys, and the gradual devastation of cultivated fields, thus proving the truth of the saying of a great naturalist, "Man strides over the earth and a desert follows him."

15. Dr. F. W. Dunkelberg, director of the Royal Agricultural Academy at Popelsdorf, in his work entitled "Die Schiffarths-Canäle in ihrer Bedentung für die Landes Melioration"† (Bonn, 1877), concurs with me in my theory relative to the decrease of water in springs and rivers, it being the result of his own observations and experience.

16 and 17. Further along during my discussion of the observed results on the Elbe, I will give the concurring views of Mr. M. W. Schmidt, of Dresden, royal director of hydraulic works, and of Mr. Maass, of Magdeburg, a member of the royal board of public works.

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*Protect the forest.

†The importance of navigable channels in the improvement of countries.

18. Mr. Robert Lauterburg, the Swiss engineer and hydraulic expert, who occupies a great deal of his time in collecting exact data and in comparing the relative discharge of the rivers of Switzerland, in his paper entitled "Ueber den Einfluss der Wälder auf die Quellen und Stromverhältnisse der Schweiz"* (published by Schulze at Basle, 1877), announces the following very reliable results of his surveys, viz:

In the Melasse formation within an area of .29 of a square mile the relative discharge of springs was accurately measured, and it was found that those in wooded portions discharged from five to ten times the amount of those in the clearings.

Now, as it is universally known that during those periods in which for weeks there is no rain the creeks and rivers are almost exclusively fed from the springs, filtration, and surface water, and also known that since the introduction of railroads and telegraphs in Europe, as well as the general and extraordinary increase in all kinds of manufactures and trade, such a colossal consumption of building and fire wood has taken place that in Europe several million hectares† of forest which formerly existed, and particularly in hilly regions, have been cut down and destroyed, it can be concluded in advance, from the result of these observations in Switzerland, and without giving the gauge readings on rivers and streams the least consideration, that during the last forty years the discharge of springs, creeks, and rivers, during low and medium stages, must certainly have decreased.

Now, I will take the liberty of showing that not only in Europe, but in the cultivated portions of other parts of the world, the discharge of their rivers and streams has also decreased during the last decade.

19. In a report made to the House of Representatives on March 14, 1874, the Commissioner of Public Lands of the United States of America expressed his fear that the continued destruction of the forests would seriously injure the public interests. At the request of the Commissioner to submit this important question to thorough experts, the American Academy of Sciences charged a committee composed of several of its members with the task. After the committee had collected accurate data and given the subject mature deliberation it made an extensive report, full of statistical information, from which I will quote only the following chief points.

The committee in this report recounts the bearing and importance of forest culture not only for timber, but also as a means of improving the general welfare, as the climatic conditions depend upon the existence of forests and deteriorate with the destruction of the latter.

The evident results of the destruction of forests are "the failing of springs, drying up of creeks, decrease in volume of water in the rivers, canals, and streams, and the increasing difference between high and low water stages in the latter." The fact that the volume of water in rivers and streams decreases in proportion to the destruction of the forests will not escape any careful observer, and America is threatened with the danger that changes will take place in the permanence of its largest rivers even, fraught with the most serious results, unless suitable measures are adopted in proper time.

The committee finally enumerated and recommended measures and precautions most suitable to stop this threatening calamity, which are nearly the same as those which I proposed in my first treatise of 1873.

Congress, appreciating these suggestions, passed an act dated August

*On the influence of forests on the conditions of the springs and streams of Switzerland.

†About two and one-half acres.

15, 1876, appropriating $60,000 for the purchase of seeds and plants and generally for the improvement and promotion of forest culture; and a further sum of $2,000 as a prize to an expert in the investigation of the question of forest and tree culture and the means which best commend themselves for the preservation, improvement, and planting of forests in North America.*

20. The above prize was won by Dr. Franklin B. Hough, through his scientific work† on this subject, in which he points out in great detail the influence of forests on the even and seasonable rainfall, upon the acquisition of a regular water supply to the springs, creeks, and rivers, and finally on the prevention of extraordinary floods, and in which he then cites the proofs furnished by my treatise of April, 1873, and agrees with me in the views therein expressed and with the theory concerning the decrease of water in springs and rivers as therein announced.

It will be seen from the official proceedings and the scientific data which have been collected, as just mentioned, that already in North America even, where, partly through the vandalism, ignorance, or avarice of the inhabitants and partly through elemental disturbances, very extensive tracts of wooded lands have been cleared and totally destroyed, the highly injurious effect thereof, and particularly the decrease in the volume of water in their springs and rivers, probably has become more evident than to us in Europe, and that also the government of that country has forthwith recognized the danger resulting from this not only to its present but also to its future generations, and that it now proposes to apply in the most energetic manner such measures as will prevent this danger as much as possible.

21. The only knowledge which I have thus far obtained relative to to this question in South America is taken from the following article, dated December 5, 1878, written from Rio Janeiro to the Cölnische Zeitung,‡ viz:

"A phenomenon is developing which causes apprehension on the part of the inhabitants on the banks of the Amazon, namely: The stream is receding in an appalling manner, and particularly above Manaos navigation is already impossible. There is a constant decrease in the stage of the river, the causes of which are wholly unknown. It is very desirable that thorough naturalists should examine this phenomenon."

Now, if such a remarkable decrease in the volume of water has been observed in the upper portion of the Amazon, which is the largest and has a greater wealth of water than any other river on the face of the globe, it is very probable that similar decrease in the volume of water has taken place in the other rivers and streams of South America, and that this cannot be substantiated for want of observations alone.

22. Mr. John Croumbie Brown, the distinguished naturalist, formerly professor of botany at Cape Town, in his book entitled "Hydrology of South Africa, compiled by John Brown, LL.D., Kirkcaldy, printed by John Crawford, 201 High street, 1875," has published very interesting

*The author is mistaken herein. The act approved August 15, 1876, directed the Commissioner of Agriculture to appoint some man of approved attainments and practically well acquainted with the methods of statistical inquiry, with a view of ascertaining the annual amount of consumption, importation, and exportation of timber and other forest products, the probable supply for future wants, &c. On August 30 1876, Hon. Frederick Watts, then Commissioner of Agriculture, appointed Dr. Frank, lin B. Hough, of Lowville, Lewis County, New York, to the discharge of this important duty.

†*Report upon forestry*, prepared under the direction of the Commissioner of Agriculture, *in pursuance of* an act of Congress approved 15th of August, 1876, by Franklin B. Hough. *Washington*, Government Printing Office, 1878.

‡*Cologne Gazette.*

observations and experiences, extending through a long series of years, concerning the former and present condition of the countries as well in Africa as in the larger islands of the Southern Ocean, of which I will briefly mention but a few.

In South Africa there are yet found scattering groups of trees of gigantic dimensions and great age, but without any corresponding after-growth, which are undoubtedly the remnants of former extensive forests which were cleared or destroyed by fire. These ancient gigantic trees prove the former great humidity of the climate and the rank fertility of the soil.

The destruction of the forests in South Africa and the custom which prevails there of destroying their tall grasses by fire have contributed very much to the parching of the soil in those localities, so that new trees are only found along the banks of rivers and in high mountain passes.

Dr. Livingston and Dr. Moffat also describe the burnings just mentioned, and the latter refers to an extensive forest of wild olive trees in the vicinity of the city of Griqua which was destroyed by fire, and mentions the gradual decrease of rainfall which resulted therefrom.

Mr. Brown notes many observations concerning the numerous and sudden changes which occur at present from severe droughts to violent rains, causing destructive overflows and the evident decrease in the volume of water, indeed the complete drying up of many creeks and rivers as well as their change into torrents; which, however, are only created when the forests and plants of the mountain slopes were destroyed and the soil was washed away in consequence thereof. In countries where mountains are covered with forests no torrents are formed, but, on the contrary, plenty of springs, creeks, and rivers, which serve to increase the fertility of the soil.

The author further reports upon the decomposition of the former rich soil by the sun's rays, by which the country becomes sterile, and the fields which were once rank are converted into deserts, and says that these very disastrous changes are, according to the scientific investigation of Mr. Brown and a naturalist cited, by him, entirely due to the destruction of the forest in those countries.

In the concluding chapter of his work Mr. Brown recommends, for the purpose of removing or at least ameliorating the evils which have resulted from the destruction of forests, measures and precautions almost identical with those proposed by me in my first treatise of 1873, although the latter was unknown to him when he compiled his work.

In the second work published by Mr. Brown, entitled "Forests and Moisture, or Effects of Forests on Humidity of Climate, compiled by John Croumbie Brown, LL.D., Edinburgh, 1877," he proves conclusively, in more detail, not only theoretically but also by numerous illustrations, the fact that forests have a great influence and effect on the humidity of the air and surface of the earth, the drying up of marshes, the formation of clouds, on the quantity and regular distribution of rain among the different seasons, and the discharge of springs and rivers. In this work Mr. Brown cited the data collected in my treatise of 1873, and declares himself as agreeing with me in my theory concerning the decrease of the volume of water in springs and rivers.

23. In conclusion, I must here advert to a fearful catastrophe which lately occurred, and strikingly proves the disastrous results of unlimited destruction of forests.

The northern province of the Chinese Empire, Shan-Si, whose capital *is Tayeun, is inclosed on all* sides by high mountain ranges, which in *early ages were covered with* dense forests. At that time it rained here

every year periodically, the atmosphere was sufficiently humid, and it belonged to the fertile, well-cultivated, and densely-settled provinces of the Chinese Empire. But the inhabitants of this once blooming and happy country, through greed and in the endeavor to increase the yield of these mountain slopes more and more, have gradually cleared the surrounding mountains completely. The result is that the former periodical rains have almost disappeared, and that the rainfall as well as the humidity of the atmosphere have decreased, and that, consequently, in this province failure of crops, want, and misery have succeeded each other during several years. In 1877, already, there was such a general drought, failure of crops, and famine, that in consequence thereof nearly three millions of souls perished. In the official report of the governor, Li Ho-nien, chief commissioner of the board of relief, the following account of this catastrophe appears, viz:

"During the first period of this unheard-of famine, the living subsisted upon the corpses of the dead; then, later, the weak were devoured by the strong; now the misery has reached such a stage that the people devour their own blood relations. History, up to this date, has not shown a more horrible state of affairs than this, and unless measures for relief are promptly taken the entire population of this section of the country will be destroyed."

The Catholic bishop, Monagatta, in a letter from Tayeun, dated March 24, 1878, corroborates the description contained in the above report of the horrible scenes enacted during the famine.

The ruinous results of the destruction of forests are also showing themselves in the other provinces of China; in the highlands by killing droughts, and simultaneously in the southern lowlands of the empire by destructive rains and overflows.

CHAPTER II.

CLEARING UP THE DOUBTS AND REBUTTING THE ARGUMENTS OF THE OPPONENTS TO MY THEORY ON THE DECREASE OF WATER IN SPRINGS AND RIVERS, AND COMMUNICATING THE NEW DATA AND OBSERVATIONS RELATING THERETO COLLECTED BY ME SINCE 1873.

So far as I have been able to learn, up to the present time, from published works and scientific periodicals, the following engineers and experts have expressed views in opposition to my theory, viz:

1. The committee of experts of the Society of Austrian Engineers and Architects, which, in its report already referred to by me, agrees with my theory in general, but doubts somewhat the proofs which I offered and the conclusions drawn therefrom.

2. Mr. Sasse, royal Prussian ministerial counsellor and member of the board of public works (Zeitschrift für Bauwesen, von G. Erbkam, in Berlin, von Jahr 1874). *

3. Mr. Kluge, royal Prussian inspector of hydraulic works (in the journal just mentioned).

4. Mr. Schlichting, royal Prussian inspector of hydraulic works (Deutsche Bauzeitung, Jahr 1876). †

5. Mr. Grebenau, member of the imperial board of achitecture and director of hydraulic works (Deutsche Bauzeitung, Jahr 1876.)†

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*Journal of Architecture, Berlin, 1874, G. Erbkam, publisher.

†German Gazette of Architecture, 1876.

6. Mr. Grave, royal Prussian district architect and deputy director of public works (Deutsche Bauzeitung, Jahr 1877.) †

7. Mr. Charles Hurich, royal Hungarian ministerial counsellor (Zeitschrift des ungarischen Ingenieur und Architecten Vereines.) *

8. Dr. Joseph Ritter Lorenz von Liburnan, imperial and royal ministerial counsellor (Wald, Klima, und Wasser, 1878.) †

These opponents urged against my theory and the proofs on which it rests the following doubts and arguments in general, viz:

A. That the decrease in the stages of water, *i. e.*, the lowering of the water surfaces shown by me to have taken place at the nine gauges on the five rivers may not have resulted from a decrease in discharge, but from a deepening of the river beds or a change in the slope caused by works of improvement.

B. That the established fact that the stages of these rivers have decreased in height does not furnish reliable proof that their discharge has decreased.

C. That it may be possible that the increased discharge of streams, produced by the higher floods of the present time, brings the decreased discharge caused by the diminished height of low and medium stage to the former general average, and then the observations furnished would only show that during the last decade the regimen of rivers and streams has undergone a change.

D. That gauge readings of a stream extending through a period of at least 200 years are necessary in order to draw a reliable conclusion from them whether a decrease in volume of water has really taken place or not.

E. That it cannot be determined with certainty from a comparison of the heights of different stages of streams whether a decrease in the volume of water has taken place or not, and that this can only be done by directly measuring, from time to time through a long period of years, the actual discharge of rivers and streams.

F. That the assertion made by me that the amount of rainfall had decreased in consequence of the great devastation and destruction of forests is not at all proven by the examples which I furnish, and the opinions of scientific authorities which I cite, because from meteorological observations extending through a long series of years in England, at Paris, St. Petersburg, and Copenhagen it cannot be deduced that the rainfall has diminished.

G. Mr. Grebenau declares that my theory relating to the decrease of volume in water is incorrect, and advances instead the new theory that the beds of creeks, rivers, and streams, are continually deepened by the erosive power of the running water, and that alone in consequence of this deepening, the heights of the water stages constantly decrease, *i. e.*, the water surface of rivers and streams sinks deeper and deeper.

Since Mr. Grebenau declares my theory incorrect, and substitutes therefor one which is entirely new in hydraulics, I propose, first, to thoroughly discuss the arguments and proofs upon which it is based, because, in case his assertions and theory should be well founded, the discussion of the other doubts and objections can be dispensed with.

In consequence of the invitation heretofore mentioned, given by the Imperial Academy of Sciences of Vienna, to all foreign scientific institutions, Mr. Grebenau, among others, was requested to give his opinion of my treatise on the decrease of water in rivers and streams, based upon his observations and experience relating to this subject.

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* *Journal of the Society of Hungarian* Engineers and Architects.
† *Forest, climate, and water.*

Upon this, Grebenau, with his characteristic tireless diligence and energy, collected the gauge readings of fourteen larger rivers and streams, compared them, combined them in various ways, at the same time studied zealously the water question raised by me, and then gave a detailed lecture as the results of his investigations, on September 6, 1876, at the general meeting of the Union of Societies of German Engineers and Architects, held at Munich, on the "Sinking of rivers, and the phenomena accompanying it," in which he communicated the following, viz*: He compared the readings of 75 gauges on 14 rivers for low, medium, and high water stages, divided them into two periods of observations, similar to the manner in which Mr. Wex did, calculated the mean of these, compared them, and, assuming that the mean of the observations at the above-mentioned stages need always only be taken into consideration, obtained the following results, viz:

The medium stage of 12 rivers, supplied with 67 gauges, receded, *i. e.*, the surface of the water sank, on an average, from 3 feet $3\frac{3}{8}$ inches, to 6 feet $6\frac{3}{4}$ inches; on the contrary, the stages of 4 rivers at 6 gauges increased in height, and, indeed, just at those at which the half periods of observation were very short, they lasting only 7, $7\frac{1}{2}$, $12\frac{1}{2}$, and $16\frac{1}{2}$ years.

From the results of these observations Grebenau concluded that in the changes which take place in the fall and rise of the river at several gauges on the same river at the same time of observation when the discharge is nearly uniform, no decrease in the volume of water can be substantiated, because if the fall of the river shown by the reading of one gauge would indicate a decrease, a rise shown at another gauge of the same river would indicate an increase in the volume of water, which clearly is impossible.

"Now, as Mr. Wex admits in his treatise that on several rivers, and particularly at nine gauge stations on the Danube, the bed of the river either raised or sunk, his theory that a decrease in the height of stages of a river or a sinking of its surface indicates a decrease in the volume of the water becomes, through this admission alone, untenable."

Grebenau further remarks concerning my theory that the great amount of the decrease in the stages of several streams established by the figures given in my treatise prove that this cannot be the result of a decrease in the volume of water, because otherwise these streams would in several hundred years be without water and their beds dry.

In reply to these conclusions of Grebenau, I believe it to be my duty to make the following explanation:

It is certainly generally known that the beds of rivers and streams which are not yet improved, or on which the improvements have just been begun, are deepened in some stretches and raised in others by the formation of bars, and that therefore in consequence of this a sinking or raising of the water may occur, from which no reliable conclusions could be drawn.

But if, from the numerous gauge readings which are submitted by me are eliminated those which were taken on stretches of the stream in which changes in the bed of the river took place, we will still find some rivers or stretches of streams which lie either in a natural unchangeable

*An abstract of the letter was published in the German Gazette of Architecture, of October 21, 1876. Grebenau had more extensively elaborated his investigations in the water question, and had prepared them for publication when, unfortunately, too soon death *tore him away* on June 23, 1877. His highly-respected widow was so kind *as to transmit to me the* manuscript for inspection; but our united efforts to publish *t were vain, in consequence* of the necessary expense, which was considerable.

bed or which have been improved from time immemorial and are in a permanent condition. The most scrupulous expert must admit that on such rivers and stretches we can justly assume that the decrease in their stages, *i. e.*, sinking of their surface, indicates a decrease in the volume of water, since it would be impossible to explain the phenomenon in any other way.

I must remark concerning the second objection of Grebenau to my theory that in my first treatise of 1873 I only expressed the apprehension lest the creeks and rivers, still replete with water, which exist in cultivated countries might, gradually, during a larger part of the year have little discharge; but, on the contrary, after heavy rains swell fearfully and become converted into torrents.

It is a historically-established fact that such changes have already taken place in the cultivated countries of ancient times, and only those can doubt it who are unacquainted with the geography and history of those countries.

It is out of the question to suppose that a stream which is created by the confluence of many creeks and rivers can ever completely dry up, because, although the rainfall is diminished by clearings, yet it will never completely have an end, and because in a large river valley the springs, creeks, and tributary rivers can never lose their water simultaneously, since the rainfall is irregularly divided among the valleys of the different creeks and tributary rivers, and the high water of the one frequently reaches the main stream simultaneously with the low water of another. The change of the tributaries into torrents cannot therefore completely dry up the main stream, but it may cause great and numerous variations in its stage, which might become excessive. It is clearly apparent from the plot of gauge readings given in my first treatise that this change has already begun in several streams of Europe.

I believe that I have thus successfully controverted the objections brought forward by Grebenau against my theory, and I will now pass to a closer examination of the new theory established by him.

Grebenau, as already stated, pointed out a considerable decrease in the lower, medium, and higher stages, *i. e.*, a sinking of the water surface of 12 rivers at 67 gauges, and explained this remarkable phenomenon by the following new theory, viz:

The mountains on the surface of the earth are being continually reduced in size by washings caused by the working power (called by later geologists the power of erosion) of running water and the adjacent depressions or valleys filled up and elevated. Grebenau then sets up the following thesis on the effect of this power of erosion of running water on the beds of streams:

1. The mud which is created when a river rises is due to the friction of the different kinds of *débris* upon each other, and the floating mud is therefore the necessary result of the rolling *débris*.

2. This mud is generated and carried farther at each point when there is rolling *débris*, and, therefore, increases continually in a downstream direction; and, indeed, according to the rule of arithmetical progression.

3. The voids produced in the *débris* by the mud thus carried off are the causes of the continued and lasting deepening of the river bed and the resulting sinking of the water surface.

Grebenau, assuming these theses as established in discussing the *Rhine, whose* water surface in Alsace, as he proves, sinks on an average *.64 of an inch annually,* and, therefore has sunk 5 feet 4 inches during

100 years, and 53 feet 4 inches during the last 1,000 years, arrives at the conclusion that about 5,900 years ago the falls at Schaffhausen did not exist, and have only been caused since that time by the sinking of the bed of the stream below, and that about 1,000 years ago the surface of its central portion below Basle was at the height of its present high banks, or 53 feet 4 inches higher than it is, and that it then washed and formed these banks and since then has deepened its bed and lowered its water surface to that amount.

If the theory of Grebenau that the beds of all rivers and streams are deepened by the power of erosion at a continuous rate of $\frac{3}{8}$ to $\frac{3}{4}$ of an inch annually—consequently from 3 feet $1\frac{1}{2}$ inches to 6 feet 3 inches in 100 years, and from 31 feet 3 inches to 62 feet 6 inches in 1,000—were considered well founded and true, it would have a very injurious effect upon the cultivation of countries and future generations. I have, therefore, since 1876, collected data and studied the question in the most thorough manner, and I take the liberty to communicate briefly the result thereof.

It is known to every hydraulic engineer and geologist that rivers and streams flowing through large broad valleys, if left to themselves, do not deepen their beds, which consist of coarse rounded gravel and *débris*, but cause their banks, which consist of lighter earthy material, to cave in, largely increase the width of their beds, create islands, bends, and swift currents, and finally, as they lose through this the most of their transporting power, the *débris* from the regions of their headwaters and tributary creeks and rivers is deposited and raise their beds.

During past ages these wild rivers and streams meandered at will in the valleys, and created their existing banks by filling up the deep gulleys and basins of the sea which previously existed. At the present time these wild streams raise their banks by deposits of mud during overflows, but not as rapidly as their beds are raised, and it frequently happens that the difference of level between the banks and bed of the river is diminished and the height of overflows increased.

It is also very well known to every experienced hydraulic engineer that the velocity and motive power of these wild streams can be so much increased by their improvement, *i. e.*, by narrowing its wide stretches, closing subsidiary channels, making cut-offs, and finally protecting its banks, thus increasing their slope; that the beds of these improved portions will be gradually deepened by the removal of the pebbles and *débris* which raised them, and that they will be enabled to move the *débris* which is brought from the region of the headwaters by high waters farther down stream. If, however, this improvement is not made throughout the whole stream this *débris* will be deposited in the lower parts thereof, and thus raise its bed and cause it again to run wild.

The fact just mentioned that rivers and streams, in their natural state, have a tendency to raise their beds, and consequently their water surface, and that a deepening of the former and lowering of the latter can only result from their thorough improvement, has been already mentioned in a detailed manner by Mr. Hagen, royal Prussian privy counselor of the superior board of public works, in his admirable manual on the knowledge of hydraulic works, and many more of the distinguished hydraulic engineers of Germany and Italy who I requested in writing to give me the result of their observations on this point have declared that after many years devoted to the study thereof they consider this an established fact, and none of them could furnish me with a single in-

stance in which the bed of a river or stream was continually deepened by the natural power of erosion of the running water.

Although it must be admitted that the friction of the particles of gravel brought down by high water against each other does cause some mud, yet it must be clear that by far the greatest part of that carried along by high water is produced by the rain washings of the valleys, by caving of unprotected banks, and finally by the *débris*, sand, and earthy matter emptied into the stream by its tributary creeks and rivers, so that a deepening of the bed cannot be even inferred from the quantity of sand carried off by a stream, much less can it be measured thereby, because that which is produced by the friction among the particles of *débris* is vastly overweighed by the very large quantity of rubble sand and earth which is brought in at every high stage from the headwaters and tributaries.

From this it follows that the theory advanced by Grebenau that the mud transported by the high water of streams is principally created by the friction of the particles of *débris* on each other, and its sequence that the beds of old rivers and streams are continually deepening through the power of erosion of their running water, is evidently incorrect, since in all rivers and streams in their natural state precisely the opposite, namely, the raising of the bed, takes place.

The incorrectness of the theory advanced by Grebenau is also proven by historical facts, for if the deepening of river beds had continually taken place in earlier times all valleys whose surfaces are now only from 6 feet 6¾ inches to 9 feet 10½ inches above the medium stage of the river must have been permanently inundated about 500 years ago, which plainly was not the case, because at that time cities and many inhabitated places existed therein. Mr. Grave in his criticism of Grebenau's theory* (Deutsche Bauzeitung von Jahr, 1877, Nos. 54 and 56) has already proven at considerable length the fact that it was opposed to historical facts.

I can leave the contradiction of Grebenau's theory concerning the creation of the falls of the Rhine by reason of the sinking of the river bed below to the geologists, who are better versed in such a subject, but I must, on the other hand, opppose in a determined manner his further assertion that about 1,000 years ago the water surface of the Rhine below Basle was on the same level with its high banks, and that it made these, and since that time its bed has been deepened about 53 feet 4 inches.

Grebenau, at the general meeting of the "Pollichia," in Dürkheim, delivered a lecture, on September 11, 1869, entitled "Der Rhein vor und nach seiner Regulirung,"† which was subsequently published as a paper, with maps and profiles attached, which proves, at great length and very thoroughly, that in prehistoric times there existed, in the present valley of the Rhine, between Basle and Bingen, a large sea which gradually flowed off, as the mountain gorge between Bingen and Bonn was formed. The basin of this sea was filled up by the large masses of rubble and *débris* brought into it, not by the Rhine alone, but also by the creeks and other rivers which emptied into it, to within from 32 feet 9¾ inches to 65 feet 7½ inches of the present surface of the valley. The high banks, also called the Dilurian terraces, which are from 3.1 to 4.3 miles apart and 32 feet 9 inches in height, were clearly once the rim of this basin, and received their present form partly through the action of the waves of this sea, which subsided very slowly and in proportion to the crown

* *German* Gazette of Architecture, 1877, Nos. 54 and 56.
† *The Rhine before* and after its improvement.

of the rocky crest of the falls at Bingen, and partly to the undermining caused by the Rhine, which meandered in this irregularly filled-up basin in the wildest manner. Since the basin has filled up, and after the slope had become regular between the crest of the overfall at Bingen and the river bed, also consisting of rock, at Basle and at Waldshut, the Rhine has not only not lowered its adjacent banks, which are composed of coarse gravel, but on the contrary has raised them from 3 feet $3\frac{3}{8}$ inches to 6 feet $6\frac{3}{4}$ inches, by depositing upon them sand and mud during its frequent overflows.

The gradual sinking of the water surface of this sea is, to-day, plainly visible on the high banks on both sides, and also the subsequent undermining of the latter by the wildly meandering Rhine, and then, in consequence of its improvement, begun in 1817, between Basle and Manheim, by straightening and shortening its length from about 165 miles to 111 miles, a deepening of the obstructed river bed and sinking of the water surface of from 3 feet $3\frac{3}{8}$ inches to 4 feet $11\frac{1}{16}$ inches took place in some stretches of the river. The excellent hydraulic engineer, Grebenau, observing these visible facts, was led to the erroneous conclusion that this deepening of the river bed and sinking of the water surface were the result alone of the power of erosion of the Rhine, and, as he at the same time found that at 67 stations on 12 rivers, during a long period, there had been observed a considerable decrease in height of the low, medium, and high-water stages, Grebenau advanced the incorrect theory that, since the existence of all creeks, rivers, and streams, without exception, their beds had been continually deepened, and their water surfaces sunk by the power of erosion of the running water, and that this erosion will continue steadily in the future.

In saying the preceding I do not wish to cast any reflection upon the memory of my departed, highly valued, and personal friend Grebenau, who was known and respected in the whole of Germany as a distinguished hydraulic engineer, but I simply desire to clear up a very important hydraulic question.

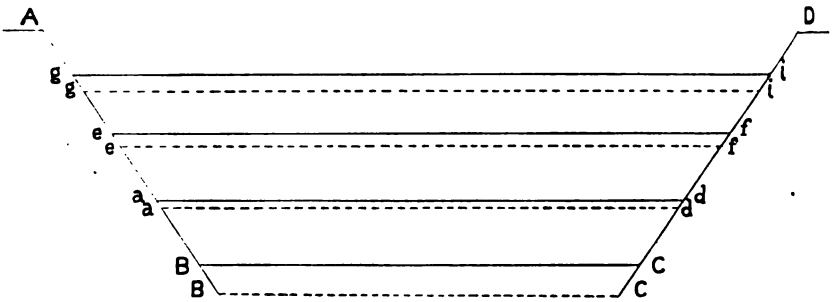
Now I will attempt to clear up, *i. e.*, to rebut, the arguments, objections, and doubts heretofore enumerated of my other opponents, and for that purpose will refer to the data and observations collected by me since 1873, and which strengthen the correctness of my theory and prove Grebenau's utterly untenable.

Reply to A.—If the decrease in height of the stages of a stream, *i. e.*, the sinking of its water surface which was observed during a long period, were alone the result of the deepening of its bed, either by the power of erosion of the running water or by the executed improvement of the stream, these deepenings must take place in a large part of the stream, must be created successively and in equal degree, and finally must be permanent.

The changes in the bottom of the bed of a river, such as partial washing out by whirlpools and shifting of the channel, which occur at almost every high stage cannot be considered as being a deepening of the river bed in the sense in which it has been herein discussed, as these are generally corrected again by the next high water, and consequently can have no effect upon the monthly or yearly average of the guage readings.

In order to judge clearly and in a reliable manner of the effect which the deepening of the bed of a stream through a long stretch has upon the *water stages thereof*, it is necessary to plot the original cross-section *of this stream, together* with the deepening in the bed and various

stages thereof, and we shall then arrive at the following unassailable conclusions:



In the above figure let A, B, C, D represent the whole cross-section and profile of discharge of a stream, which for the sake of simplicity we can assume as perfectly regular and with sloping banks. In this section let the line *a d*, *e f*, and *g i* represent respectively the low medium and high stages of water.

If, then, after a lapse of a long period of time, say from twenty to thirty years, the bottom of the original bed B C has been deepened to the new bottom B C, either in consequence of the power of erosion or the improvement of the stream, we can calculate the resulting amount which the surface of the water has sunk, provided we assume that the volume of water has remained the same.

Denoting the width B C of the bottom of the bed of the stream by b, the velocity of discharge by v, and the distance which the bed has sunk by h, the amount of discharge, m, through the deepened portion of the bed B B, C C, we will have

$$m = b\ h\ v.$$

Now, denoting the width of the water surface at low, medium, and high stages respectively by b, b_2, and b_3, the mean velocity at the surface at these stages respectively by v, v_2, and v_3, and the sinking produced by the deepening of the bed respectively by h, h_2, and h_3, it follows that since the volume of water is only reduced by the amount which flows through the deepened portion B B, C C, the following equations are true, viz:

$$m = b\ h\ v = b\ h\ v = b_2\ h_2\ v_2 = b_3\ h_3\ v_3.$$

Now, since in the cross-section of all streams, excepting in the rare case where both banks are reveted with vertical walls, the width of the water surface increases with the height of the stage, that is, $b_2 > b$ and $b_3 > b_2$, and since, as is well known to every hydraulic engineer, the surface velocities increase with the height, that is, that $v_2 > v$, and $v_3 > v_2$, it follows that the amount of the sinking of the water surface at higher stages must be in the inverse ratio of the product $b_2\ v_2$ to $b\ v$ and $b_3\ v_3$ to $b_2\ v_2$, and must therefore become smaller and smaller as the river rises, that is, $h_2 < h$ and $h_3 < h_2$.

It is evident from the above that the following criteria must be true in regard to decreases in the height of the water stages, *i. e.*, in the sinkings of the water surface which result from a permanent deepening of *the river bed.*

1. *The decrease in the height* of the water must be greatest in low stages,

and must be proportionately less in higher stages, and must reach its minimum in floods.

2. The decrease in the height of the water which results from the deepening of the river bed must be the same, for the same average monthly stage, because this deepening only takes place slowly and gradually during a long period of years, and the stream may therefore be considered as unchanged during the period of a year.

3. If the gauge readings of a long river, taken in the same period of time, are compared, the amount of sinking of the surface, due to works of improvement or deepening of the bed, will never be the same at the different stations, but on the contrary vary greatly from each other, because on a long river only some especially bad stretches are improved gradually and in different periods of time, and because many stretches which are in a better condition, and especially those inclosed in rocky banks, are left unchanged, and because it frequently happens that the various stretches are improved according to different systems, which as the nature of the evil varies may have quite different effects upon the stream; and finally, because in the lower unimproved portion of the river, bars, sand banks, and raising of the bed occur, and therefore it happens that an equal amount of the deepening of the bed and sinking of the water surface resulting therefrom throughout the whole river is impossible.

4. When a river is radically improved, and particularly when it is considerably shortened by means of cut-offs, its bed will not only be deepened, but its slope and the velocity of its current will be increased, and as a result of this its water surface will be lowered, and sometimes even more than by deepening its bed.

But these sinkings of the water surface must possess these criteria: that they are equal at the same station, during the same months, at the same stages, independent of the years, and that even in the same improved portions of a long river they will vary with the extent and manner of the improvement; and finally, that a sinking in the water surface cannot take place on those portions of the river near its head or mouth which are not affected by the works of improvement.

In order to furnish the proof that the considerable decrease in the heights of the stages of European rivers, *i. e.*, the sinking of their water surface, as shown by me as well as by Grebenau, director of hydraulic works, to exist, did not result in consequence of the power of erosion of the water nor from the partial improvements made of these rivers at different periods of time, but is solely due to a decrease in their discharge, I procured authentic gauge readings at numerous stations on the Rhine, Danube, and Elbe, divided them into two equal periods of observation, calculated for each the monthly and annual mean stage, as well as the highest and lowest stages which occurred, and plotted them on sheets 1 to 6, in order that they might be more readily seen and compared. These sheets clearly exhibit the observations taken during a long period of years, and from them the following conclusions can justly be drawn, viz:

(*a.*) The decrease in the height of water stages, *i. e.*, sinking of the water surface of the Rhine and Elbe, is in direct opposition to the criterion laid down in my preceding reply to A under the head of 1; that is, it is the least at low and increases considerably at medium and high stages, and can, therefore, not be the result of a deepening of their beds.

The decrease shown at the six stations on the Danube did not agree with the above, because, as will hereafter be shown, the stations at Dil-

lingen, Linz, Vienna, and Pesth were changed during the period of observation.

(*b.*) The decrease in the height of water stages at the same stations, at the same stages of the river and during the same months varies considerably, and the amount thereof depends far more upon the season of the year than upon the mean stage of the rivers, and this observed result further proves that the sinking is not due either to the deepening of their beds or to their works of improvement.

(*c.*) It will be further seen from these plottings that at several stations on the same river, even when they are separated by great distances, non-improved portions and stretches flowing over rock, the decreases in the height of the water surface, for the separate months, are the same or very nearly so, which does not agree with the criteria laid down in Nos. 3 and 4 of my reply to A.

RESULTS OF SPECIAL OBSERVATIONS ON THE RHINE.

It will be seen from the plotted gauge readings at the six stations on the Upper, Middle, and Lower Rhine, that the decrease in the height of the water surface is the greatest in the summer months of June, July, and August, and least in the winter months of November, December, and January, although the high water of summer which is poured down by the melting of Alpine glaciers and snow has already reached a medium stage when it arrives at Cologne and Emmerich; and, on the contrary, the winter low water of the Upper Rhine becomes high water at Emmerich by the addition of the water from its tributaries; consequently the Rhine completely changes its nature and regimen in this distance of 422½ miles.

Mr. Von Salis, Helvetic chief inspector of public works, established the fact that the bed of the Rhine at Basle has not deepened during the relatively short period of observation from 1857 to 1872, in a communication to the Imperial Academy of Sciences at Vienna, dated April 17, 1875, from which the following is an abstract, viz:

"Gauge readings have been taken at Basle since 1808, which may be of value in discussing the question of decrease in the volume of water since the station has been fixed, and the geological condition of the river bed precludes the assumption of any deepening and in general of any change therein."

Mr. Honsell, member of the board of public works of the Grand Duchy of Baden, who is in charge of the works in the district beginning at Constance and ending at the Hessian frontier, in his letter to me dated November 30, 1877, has furnished overwhelming proof that there has been no deepening of the bed of the Rhine either at Basle or Waldshut, by pointing out the great firmness of its bed, which is composed largely of rock, and the relative level of the old bridge across the Rhine, built about the year 1225, and the streets of Basle. He concludes his letter as follows, viz:

"The assertion made by Grebenau that the bed of the Rhine is sinking or deepening must, therefore, so far as the neighborhoods of Basle and Waldshut are concerned, not only be described as improbable, but absolutely impossible."

It is certain also that there has been no deepening of the very rocky bed of the Rhine in the mountain gorge near Bingen during the short period from 1857 to 1872.

Now, if the Rhine at the four other stations shows, in the separate *months during the half* period of observations between 1857 and 1872,

a decrease in the heights of its water surface similar to those at Basle and Bingen, it is perfectly justifiable to conclude that neither the partial improvement of the river nor a general deepening of its river bed, but another cause which operates uniformly throughout its whole length, has produced the decrease in the heights of the water surface at the medium stages, and it is apparent that this cause can only be the decrease in the discharge, which varies from month to month according to the amount of the rainfall.

In 1817 the Royal Prussian Government ordered that the most important gauge stations on the Rhine at Cologne and Emmerich be improved, and that their zero be placed 2 feet and .62 inch below the lowest water known at that time, and this was done. In his admirable hydraulic work, Dr. H. Berghaus publishes tables of the gauge readings at Emmerich from 1770 to 1835, and expressly remarks that he reduced the readings from 1770 to 1817 to the new zero of 1817, whose height above the sea he places at 34 feet 3.44 inches.

Mr. Kluge, royal Prussian inspector of hydraulic works, at my request, kindly furnished me with his official readings of the gauge at Emmerich from 1827 to 1873, and I was thus enabled, by comparing the tables between 1827 to 1835, which were before me in duplicate, to substantiate the fact that the zero of the gauge had remained undisturbed since 1817.

Since the comparison of the accurate readings of the very important gauge at Emmerich during a period of 104 years, *i. e.*, from 1770 to 1873, is very interesting and quite sufficient to decide the question of the decrease of the volume of water in the Rhine, I have plotted them on Sheet 2, in order that they may be better comprehended.

Now, if the period from 1770 to 1835 be divided into two periods of 33 years each, and the other 38 years be considered as another period, and the relative gauge readings in these three periods be compared, the following noteworthy phenomena will appear:

During the period from 1770 to 1820 the variations in height of the annual high and low water, as well as mean stages, were very slight, excepting in the case of a few years. From 1820 to 1873 it will be noticed that there were very frequent and considerable rises and falls in the high, low, and mean stages, and more frequent changes between years of abundant and small water supply.

The flood of 1861 rose 9.45 inches above those of 1799 and 1809, and the low water of 1865, 1866, and 1870 fell from 3 feet 7.3 inches to 4 feet 0.42 inches lower than the lowest of the first period, that of 1802; consequently the difference between the highest and lowest stages in the latter period has increased 4 feet 9.9 inches.

In the last period of 38 years, from 1836 to 1873, the arithmetical mean heights of the water stages decreased in comparison with those of the period from 1770 to 1802 as follows, viz:

The monthly stages from 10.63 inches to	4 feet 4.55 inches.
The annual stages	2 feet 4.4 inches.
The highest stages	11.46 inches.
The lowest stages	2 feet 2.2 inches.

The observations just mentioned furnish perfectly explicit additional proof that in the last decades the Rhine at Emmerich has undergone a considerable change in its character and regimen, and from which we may conclude that there has been a change in the rainfall in the whole region of its headwaters. Furthermore, since there have been no extensive and radical improvements of the Rhine by cut-offs at Emmerich *since 1802, the foregoing* considerable decrease in the stages of the river,

i. e., the sinking of its water surface at all stages and seasons, can only be explained by the circumstances that its discharge must have decreased considerably.

The reason why the decrease in the height of water surface proves to be greater at Emmerich than at the five upper stations is that the decrease of the volume of water in the whole upper river valley, and in all the springs, creeks, and rivers which emanate therefrom, are all concentrated there.

RESULTS OF SPECIAL OBSERVATIONS ON THE ELBE.

It will be found, from the plotted readings on Sheet 3 of the gauges on the Elbe at Dresden, Riesa, and Magdeburg, from 1837 to 1872, and those on Sheet 4, taken at Dresden during a period of 68 years, from 1806 to 1873, that almost the same circumstances exist relative to the decrease in the height of its water surface and increase in its variations as have been described in the foregoing paragraph on the Rhine, and, therefore, I will not discuss them here again.

A more comprehensive view of the decrease of water in the Elbe can be obtained from the plotted readings of the gauge at Magdeburg, taken during a period of 142 years, from 1728 to 1869, which are given in my first treatise of 1873. The data described in detail in the latter, and which were collected by the international technical commissions for making examinations of the Elbe in 1842, 1857, and 1869, are not only very interesting, but fully sufficient to enable a conclusion on the question before us, relating to the decrease in height of stages in that river and sinking of its water surface, to be reached. They establish the fact that the low-water of September, 1842, was from 3.9 to 11.4 inches lower than those marked on the rocks in the river beds at Tetschen, Pirna, and Strehla for the years 1616, 1706, 1719, 1746, 1782, 1790, 1800, 1811, and 1835, and it was, therefore, the lowest during a period of 226 years.

It will be seen from the readings collected by the subsequent commissions for making examinations of the Elbe, and which I have tabulated on Sheet 3 for all of its stations to the head of tide water at Blekede, that in 1852, 1857, 1869, and 1873 the low water of its upper portion, which is thoroughly improved to Dresden and Wittenberg, by means of training walls, fell about 10 inches below that of 1842, and that, on the contrary, in the lower river, which is only improved in stretches by quay walls, the bed was raised by sand banks and the low-water stage raised.

Mr. M. W. Schmidt, royal Saxon director of hydraulic works, published in the "Civil Engineer," in Nos. 4, 5, and 7 of volume 24, valuable information in reference to the slope and gauge readings of the Elbe, in the kingdom of Saxony, and this expert expressed the opinion, based upon accurate hydraulic data, that during the last decades the mean monthly and annual, and particularly these low-water stages of the Elbe, in summer and fall, have decreased considerably, and to the extent of 2 feet 0.4 inch at the station at Dresden, and from 1 foot $3\frac{3}{4}$ inches to 1 foot 6.1 inches at Riesa.*

Mr. Schmidt further proves that in consequence of the improvements which were made on the river, a deepening of its bed and sinking of its water surface took place, which amounted to 1 foot $2\frac{1}{8}$ inches at Dresden and to $7\frac{7}{12}$ inches at Riesa. Since the actual decrease in the height of

**The gauge stations at Meissen are not mentioned here, because the period of observation has been too short, and the effect of the improvements of the river made at that point has not yet been determined.*

water surface has become 10¼ inches greater at Dresden, and from 7 1/12 to 10¼ inches at Riesa, it is the opinion of Mr. Schmidt, "in view of the strange phenomenon, that some other cause, not resulting from the works of improvement, must have been in operation to produce this sinking in the mean stages of the water, and which, taking all the surrounding circumstances into consideration, can only be that the volume of water in the Elbe has diminished during the last twenty years. Attention may be called to the fact that after the most thorough researches of the imperial royal counsellor Wex on other European rivers, he announced in 1873 the same conclusions which have been arrived at by the observations of the height of the water in the Elbe."

Mr. Maass, of Magdeburg, member of the royal Prussian board of public works, who has made the most thorough study of the circumstances connected with the height of the water and drifting of the ice of the Elbe, and has published the result thereof, also gives, in his letter to me dated January 31, 1878, it as his opinion that the decrease in the height, *i. e.*, the sinking of the water surface of the Elbe, is due partially to its improvement and partially to the decrease in its volume of water which has taken place.

Engineer Urbata, in "Stummer's Engineer," of 1875, ascribes as a reason for the decrease of the volume of water in the Elbe, which has been universally observed, not only the clearing of the forests, but also the total drainage of ponds. Emperor Charles IV ordered the construction of ponds in the kingdom of Bohemia at the public expense, and at the end of the sixteenth century the total area of these amounted to 540½ square miles, of which it is said only about to the extent of 58 square miles now exist.

RESULTS OF SPECIAL OBSERVATIONS ON THE DANUBE.

In making the comparison between the mean of the monthly and annual readings at the most important stations on the Danube, which are plotted on Sheet 5, I could not choose periods of observation of equal lengths, because unfortunately some are quite short, and because the cross-section and the discharge of the Danube have materially changed at several stations during the last decades. Correct conclusions from the comparison of the mean-water stages can, therefore, only be drawn by considering them in connection with the changes that have taken place in the cross-section of the river. I have therefore obtained the oldest as well as the latest cross-sections as determined by experts in the public service at the four stations at Linz, Stein, Pesth, and Old Orsova, have accurately plotted them on Sheet 6, and will now briefly discuss the results of the comparison of the gauge readings at the separate stations; at the same time, take the changes in the cross-section of discharge into consideration.

The Danube at Dillingen.

Mr. Bernhard V. Herrmann, of Munich, chief director of the royal Bavarian board of public works, in a letter to me dated December 3, 1877, was so kind as to communicate to me that in his opinion the quite considerable decrease in the height of all stages, *i. e.*, in the sinking of the water surface of the Danube, at Dillingen, in Bavaria, which was observed during the second half of the period comprised between 1835 and 1874, *is due to the* improvement of the Danube, which has been *energetically prosecuted* during the last decades.

The plot of the gauge readings at Dillingen is worthy of notice, inasmuch as the following conclusions can be drawn therefrom, viz:

The slight variations between the monthly mean, as well as the small increase in height of high-water and slight decrease in height of low-water stages, indicate that large tracts of forests still exist in the region of the headwaters of the Danube, and regulate the flow of its water at Dillingen.

The fact that the variations in the monthly mean as well as in high and low water stages are so uniform, observed during the second half of the period included between 1855 and 1874, proves that the extensive river improvement at Dillingen has not only deepened its bed, but has also increased the velocity of its current considerably.

The plot of the gauge readings at Dillingen may therefore be considered as a prototype of the relative water stages of such rivers whose discharges are regulated by large forests existing in their valleys, and also for such as have been extensively and radically improved, and particularly of those in which the slope has been increased by diminishing their lengths by cut-offs. Now, as none of my plots of the gauge readings on many other streams and at various stations resemble this prototype at Dillingen, as far as regards the very uniform stages of water and their nearly equal variation at all seasons of the year, it follows that the causes which are at work at Dillingen either do not exist at all at the other stations and on the other rivers, or exist in only a very slight degree.

The Danube at Linz.

The plot of the gauge readings at Linz, taken during the second half of the period included between 1849 and 1875, shows scarcely any variation in the months of April, May, June, July, and August, which are the five richest in water supply; but, on the contrary, during the other seven months, shows a decrease in the height of water stages or sinking of the water surface of from 1.42 to 8.32 inches, of 4.8 inches in the annual mean, of 7.22 inches in high and 0.5 inch in low stages of the river.

It will be seen, however, from the cross-sections of the river, accurately taken in 1850 and 1877, only 54 feet 8 inches above the gauge at the bridge, and which are plotted on Sheet 6, that the cross-section of discharge was diminished by the construction of terraces and revetment of the river banks about 452 at the zero, about 646 at the medium, and about 1,604 square feet at the 19-foot 8-inch stage; and that in consequence of this decreased cross-section the surface of the water during the period included between 1850 and 1875 must have been raised as follows, viz: At the zero stage, about 6.66 inches; at the medium stage, about 9.84 inches; and at the high stage, about 1 foot 10.41 inches.

If, therefore, the cross-section of discharge had not been diminished, the sinking in the water surface of the river during the second half of the period included between 1849 and 1875 would have amounted as follows, viz: At the zero stage, to about 7.8 inches; at the medium stage, to about 1 foot 1.12 inches; and at the high stage, to about 2 feet 4.44 inches.

This can only be the result of a decrease in the discharge of the Danube at Linz, since it has not been improved at that point, and there has been no deepening of its bed.

The Danube at Stein.

The gauge readings of the Danube at the city of Stein, near Krems, *are of the highest importance* in this discussion, because at that place

one of the oldest wooden pile bridges spans the Danube, and there is a wharf which is very much used. In consequence of the frequent renewal of the piles of this bridge, and the examinations made to determine the best location for its draw, frequent accurate cross-sections of the river were taken, and the gauge readings since 1829 were also preserved. I found, in prosecuting my researches, that no improvement of the Danube was made after 1829 until 1874, when its bed was narrowed at the bridge; and, therefore, I have considered neither the alterations in the water stages nor changes in the bed of the river caused thereby since 1874.

I also obtained the official cross-sections of the stream taken at the bridge at Stein in 1838, 1848, 1858, 1869, and 1872, compared them, and finally plotted the first and last ones together on Sheet 6. From these it will be seen that the bottom of the river-bed,* which is here composed of gravel, was, it is true, at times deepened by high waters, but then again filled up by them, so that the mean depth of the cross section taken in 1872 differs only .2 of an inch from that of the one taken in 1838. It follows from this that a general sinking of the bottom of the river bed was not effected by the power of erosion of the running water, and that, therefore, Grebenau's theory seems unfounded.

Now, it will be perceived by examining the plotted gauge readings at Stein on Sheet 5, that in the second half of the period included between 1853 and 1873, the heights of all stages of the river have decreased, as follows:

The mean stages by from 3.08 inches to 1 foot 4.58 inches; the annual mean stages by 8.58 inches; the mean high stages by 1 foot 10.76 inches; the mean low stages by 8.47 inches.

Now, as the Danube was not improved at Stein, nor any deepening in the bottom of its bed took place, the assertion that this decrease in its water stages is alone due to the decrease in its discharge can be made with the fullest justification.

The Danube at Vienna.

The changes which have taken place in the cross-section of discharge of the Danube at Vienna could not be determined, because it was divided at this place into two large arms and the Vienna Danube Canal, which is 54 yards and 2 feet wide, and because a number of smaller subsidiary channels which existed just below the city were closed. It can, however, be generally asserted that the cross-section of discharge decreased considerably during the period included between 1851 to 1874, by reason of the fact that the southern arm, the so-called "Kaiserwasser,"† 162 yards wide, which formerly was 6 feet 6¾ inches deeper than the zero, and which had a considerable discharge, is so filled up that now, at the zero stage, there is none, while at the same time the cross-section of discharge of the northern arm has changed but little.

If, notwithstanding this, the tabulated comparison of the water stages and the plot thereof on Sheet 5 show that the monthly and annual mean as well as the high and low water stages for the period included between 1851 to 1874 have decreased from 5.1 inches to 1 foot 8.9 inches,

* The original supposition of the government experts, that a portion of the river-bed was rocky, was subsequently proven to be incorrect by the deepening which took place; and *the rocky ledge*, which shows itself in the river-bed about 1,968 yards *below, either does not reach* up to the bridge, or, if it does, lies at a great depth.

† *Imperial stream.*

as they do, it follows that the discharge of the Danube has decreased during that period.

The gauge readings since 1874 are not considered in this discussion, because the cut-off at Vienna, which has the normal breadth and depth of the stream and a length of 4 miles and 13 yards, was opened in 1875, the old channel completely closed, and the gauge station transferred to the cut-off, and therefore no reliable conclusions could be drawn by comparing the readings before and after the opening of the cut-off.

The Danube at Old Orsova.

The gauge readings of the Danube at the city of Old Orsova are very important and very satisfactory in the discussion and decision of this question of the decrease in the volume of water, because all the larger tributaries empty into the stream above this place, and, being in consequence thereof a mighty stream, replete with water, the abnormal stages of water in single tributaries, caused by particular elementary actions in their valleys, have no influence on its discharge at Orsova.

Again, in consequence of the great difference in the configuration, composition of the soil, and climatic conditions of the several valleys of the tributaries which flow into it from the south, west, and north, these carry off their high and low water, at different times, the Danube at Orsova may be considered as a great recipient and regulator of the high, medium, and low waters of its tributaries.

For these reasons, the most reliable conclusions relative to the discharge of the stream produced by the water which it receives from its whole upper valley can be drawn from the gauge readings at this station, but only then if it is proven that during the period in which the readings were taken there has been no change in the direction of its current, its cross-section of discharge, or in its slopes.

It can be seen from any large river map of Europe, and from works published on hydraulic subjects, that the bed of the Danube for a distance of 65.86 miles below Orsova is situated in a vast mountain gorge of the southern chain of the Carpathian ranges, and that throughout this whole distance its sides, and throughout most of it its bottom, consists of rock, from which it may safely be inferred that the direction of its current and its cross-section have remained unchanged during centuries.

It will further be seen from the plan and cross-sections made by the very intelligent Hungarian hydraulic engineer, Paul Vásárhelyi, between 1832 and 1834, which I published, together with a lecture entitled "Ueber die Schiffbarmachung der Donau am Eisernen Thore und an den sieben Felsenbänken oberhalb Orsova,"* in the "Zeitschrift des österreichischen Ingenieur und Arcaitekten Vereins,"† in No. 10 of 1872, that at a point 961.85 yards above Orsova the Danube had a nominal width at the zero stage of 462½ yards and a depth of 38 feet 10½ inches in the center of its channel.

Now, since Sir John Wawra, imperial and royal director in chief of the board of public works, who was sent to Orsova as a member of the international commission of experts to devise plans for the improvement of the Danube, took its cross-section in 1873 in the most careful manner, which cross-section is plotted on Sheet 6, and found that the river, at a point 961.85 yards above Orsova, was 463½ yards wide and 38 feet

* *On making the Danube navigable* at the Iron Gate and at the seven rocky ledges *above Orsova.*

† *Journal of the Society of* Austrian Engineers and Architects.

5¼ inches deep in the center of its channel, the proof is furnished by the approximate coincidence of these measurements that at Orsova the bed of the river, its depth, and its cross-section of discharge have remained unchanged since 1832, which is quite natural, since its cross-sections are bounded by rocks, both above and below that city, and make a change therein impossible.

Although it is true that the first private "Danube Steam Navigation Company" between 1847–1849, and subsequently in 1855, the imperial royal Austrian Government did remove, by blasting, some projecting rocks which endangered navigation at the lower end of the falls at the Iron Gate, yet these could not have the least influence upon the stages of the river at Orsova, because the sections of the removed rocks were insignificant compared to the cross-section of the river, and because they were a part of a ledge which is situated 5.9 miles below that city at the foot of the falls, consequently below its crest, and whose surface is about 23 feet below the zero of the gauge at Orsova.

Now, as it can be seen from the profile of the river, which I published in 1872, that, between Orsova and the Iron Gate and at the distances of 2.8 and 4.04 miles, two continuous ledges of rock, whose upper surfaces lie only 4 feet 4 inches and 4 feet 8 inches below zero, stretch entirely across the river bed, it follows further that it would be a downright impossibility for the slope of the Danube to have changed at that point, and it can therefore be safely asserted that, during the period from 1840 to 1875, in which the gauge readings were taken, the direction of the current, cross-section, and slope of the Danube remained unchanged at Orsova.

A comparison of the tabulated readings of this gauge, taken during the second half of the period of observation between 1858 and 1875, and the plot thereof, as presented on Sheet 5, will show that the mean of the monthly and annual as well as the high and low water stage has decreased from 6.18 feet to 2 feet 5 inches, and this general decrease in the volume of water, *i. e.*, in the height of its water surface at Orsova, can only be accounted for by the fact that the discharge of the stream has diminished there.

It is notorious that, during the last decades, in several of the tributaries of the Danube—as, for instance, the Theiss and the Save—the floods sometimes rise higher than they formerly did, and their discharge is thereby increased, and that their floods are frequently poured into the great bed of the Danube and pass Orsova simultaneously with the water from other tributaries which are at a medium or low stage, yet the gauge readings, taken during the second half of the period of observation, show that these accumulated waters no longer reach the same height which they formerly did, and that the heights of the greatest floods are not as great as they formerly were by 1 foot 9.65 inches. The facts thus furnished by the large masses of water, collected together by nature itself in the Danube at Orsova, certainly will furnish every one with clear and indisputable proof that the high floods which sometimes occur in several of the tributaries do not compensate for the continued decrease in the discharge of the others at their low and medium stages.

By comparing the readings of the six gauges on the Danube it will be seen that at Stein, Vienna, and Orsova the decrease in the height of the water stages is greatest during the month of October; consequently, a uniform cause throughout the whole valley must have operated to produce the uniform effect, and that cause must have been a decrease in the rainfall.

It will also be seen by this comparison that the regimen of the Dan-

ube is partially changed in its course from Linz to Orsova, as the greatest discharges at Linz, Stein, and Vienna take place during the months of June, July, and August, *i. e.*, during the period when the snow on the Alps melts, and on the contrary at Orsova during the months of April and May, *i. e.*, during the rainy season of spring.

Although the foregoing proof, furnished by the decrease in the discharge throughout the whole length of the three principal rivers of Central Europe, *i. e.*, the Danube, Rhine, and Elbe, of the correctness of my theory in regard to the decrease in the volume of water in springs and rivers would seem to suffice, I have, nevertheless, in the interest of science and for the purpose of inciting the arrangement and publication of further observations pertinent to this subject, and finally, in order to make the thorough study of this highly important hydraulic question by my fellow professionals and naturalists more easy, at the end of this treatise added a tabular exhibit compiled from the gauge readings collected by me and Mr. Grebenau at 51 stations on 13 rivers. These readings were divided into periods, and from these the annual mean height of the water stage, as well as of the high and low stages, were calculated, and finally from these ascertained the decrease in the readings during the second half of the period of observation, in order that the latter at separate stations and rivers could be more easily compared with each other.

I take the liberty of giving the following explanation of the manner in which the calculations for this exhibit were made. I not only calculated the monthly mean stages because a comparison of the latter shows not only the changes which took place in the regimen of the rivers, but also clearly the fact that the decrease in the height of their water surfaces could not be alone explained by a deepening of their beds.

In this tabular exhibit of gauge readings I took the mean of the various high and low water stages which occurred in each year, but even these do not furnish so clear and instructive a picture of the relative discharge of a river during long periods as the plots of its lowest, medium, and highest stages which I presented in my first treatise for the Rhine, Danube, Elbe, Vistula, and Oder, and in this on Sheets 2 and 4 for the Rhine at Emmerich and the Elbe at Dresden. By an examination of the annexed tabular exhibit and the calculated means of the gauge readings at 51 stations on 13 rivers, the following important conclusions may be drawn, viz:

1. Of the 160 differences in the gauge readings which are given in the table, 149 show a decrease and only 11 an increase in the height of water stages, and it can easily be proven that the latter were caused either by the present increase in the height of flood stages or by a decrease in the cross-section of discharge or by the bottom of the bed of the stream being covered with sand.

2. The average annual decrease in the height of the water surface, *i. e.*, sinking of the water surface, is not only different on different rivers, but also for the different stations on the same river, and this is also the case with the low, medium, and high water stages, and evidently result from a difference in the amount of the rainfall in the different parts of the valleys. Not only the decrease in the water supply caused thereby, but also the deepening of the river bed resulting from works of improvement at certain localities, and finally, also, the configuration of the cross-section of discharge must have exerted a great influence in lowering the water surfaces. For this reason Grebenau's attempted calculations, based upon an equal mean in the decrease in the height of the water surfaces for all of the 14 rivers and 75 gauge stations discussed by him, as well

as for the different stages thereof, are entirely inadmissible, since only incorrect results can be obtained from them.

3. Since the closest examination of the plot of the gauge readings on the five rivers, Rhine, Danube, Elbe, Vistula, and Oder, presented in my first, as well as in this treatise, does not reveal that in the case of these rivers the number of the years which are rich or poor in water supply is not fixed in duration, or that they change regularly, or finally that they return at fixed periods, it cannot be determined during how many years gauge readings must be taken in order to be able to calculate from them a thoroughly reliable mean, and consequently cannot be determined, either theoretically or by experience, how long it is absolutely necessary that the two periods of observation which are to be compared should be. But it is clear to all that the longer the periods of gauge readings are, the more correct and reliable will be the mean calculated from them, since the years which are either very rich or poor in water supply, and which undoubtedly occur in the one or the other of these periods, have so much the less influence upon the calculated mean.

In consideration of the foregoing, the calculated decrease in gauge readings given in the annexed exhibit must have a greater value than such as were deduced from readings made during a shorter period.

It is also clear from this exhibit that the mean decrease in the height of the water derived from readings taken during a shorter period, and that the sinking of the water surfaces has become considerably greater in the last decades than formerly, which is explained by the fact that in the last decades there have been a greater amount of clearing, drainage of ponds and marshes, and improvement and irrigation of large tracts.

No.	Names of rivers and gauge stations.	Sinking of the annual mean of the gauge readings
		In inches.
	I.—RHINE.	
1	Basle	0.114
21	Bingen	0.24
25	Emmerich	0.40
	II.—DANUBE.	
31	Stein	0.41
32	Vienna	*0.425
34	Old Orsova	0.9
	III.—ELBE.	
35	Dresden	*0.197
40	Magdeburg	0.394
	IV.—VISTULA.	
42	Cracow	0.433
43	Kurzebrack	0.558
	V.—ODER.	
44	Küstrin	0.114
	X.—SEINE.	
53	Paris	†0.59
	XI.—GLOMMEN.	
54	Nastangen	0.11
55	Sarpfos	0.24
	XII.—MISSISSIPPI.	
56	Natchez	0.697

* The amount of the sinking of the water surface due to the deepening of the bed by improvement of the rivers was deducted at Vienna and Dresden.

† At Paris the *mean of the* decrease in gauge readings at the highest and lowest stages were taken.

4. From the annexed tabular exhibit the foregoing schedule is obtained by considering only the variations of the mean stages which are really the most noteworthy, at the most important stations at which material changes have taken place in the bed of the stream, and finally those that are derived from readings made during the longest periods.

From the schedule it will be seen that the decrease in the gauge readings increases in different rivers with the greater extent of their valleys, which seems to me to be another proof that the decrease in their discharge is due to a decrease in rainfall and the consequent decrease in the volume of water.

Reply to B.—The supposition of some of my opponents that it cannot be reliably concluded from a decrease in the gauge readings on a river that its discharge has decreased is unfounded, as the following proofs will show:

Mr. Grebenau, who was known as one of the most skillful hydraulic experts in the measurement of discharge of rivers and streams in Germany, while stationed at Germersheim in his former rank of inspector of public works, measured the cross-section, the slope, and the velocity of the current of the Rhine thirty-eight times at six points near Neuburg, Pforz, and Germersheim, and with all possible accuracy, and from these he calculated the quantity of water which the Rhine had discharged during the period of twenty-eight years included, between 1840 and 1867, which calculations I published in my first treatise of 1873. From these measurements Mr. Grebenau calculated the mean discharge of the Rhine, during the period from 1840 to 1867, to have been 41,596 cubic feet per second, and that the reading of the gauge at Sonderheim, corresponding to this discharge, should be + 3′3.3685″. The arithmetical mean of all of the readings taken at this gauge during the above period was found to be + 3′ 1″, so that the difference between the two amounted to only 2.3685″.

Mr. Grebenau, in communicating the result of these measurements to me in his letter dated February 2, 1872, gives the following opinion, viz:

"From this it follows that the mean stage of the river nearly corresponds to the arithmetical mean of the gauge readings, and that the error would have been small if in the beginning the discharge of the Rhine had been deduced from this arithmetical mean. This is a new and not unimportant law, which saves great and extensive calculations."

Grebenau, in his pamphlet on the results of gauge readings on the Rhine and Mosel, published in 1874, on page 20 makes the following remark bearing upon this point:

"Although the annual mean discharge of the Rhine deduced from the mean stage is nearly in the same ratio as the mean of the gauge readings, yet it does not follow from the difference in these mean stages, which was observed during the two periods, before and after 1840, that its discharge has decreased, since the difference is solely the result of the improvement of the river."

That the mean discharge of other rivers can be nearly accurately calculated from the mean of the gauge readings is apparent from the following results of measurements:

Mr. Harlacher, professor of the science of engineering at the German Polytechnical Academy, at Prague, measured with the greatest accuracy the discharge of the Elbe at Herrnskretschen, on the boundary *line* between Bohemia and Saxony, at the same cross-section, and at its *various stages, and calculated* from these the discharge during the *twelve months, from July* 1, 1871, to the end of June, 1872, and although

during the period there were five floods (and among them the extraordinary one of May, 1872, caused by bursting of clouds), nevertheless, Mr. Harlacher found that the difference between the mean of the gauge readings and the height of the water surface due to the mean discharge of the river, during these twelve months, amounted to only 3.15 inches, and after a more accurate calculation to only 1.575 inches. (See "Beiträge zur Hydrographie Bohmens," von A. R. Harlacher, Prag, 1872 and 1875.*)

It should here be remarked that in both cases calculated by Grebenau and Harlacher the mean of the gauge readings was smaller than the height of the stage corresponding to the mean discharge; furthermore, that the difference amounted to nothing in months during which only moderately high waters occurred, as will be seen from Harlacher's calculations, and on the contrary in months during which very high waters occurred the difference becomes somewhat greater, but yet on an average, during long periods, it will be found very small.

Now, as it may be assumed that the conditions just mentioned existed in the other streams during the various periods of gauge readings, and in further consideration of the fact that the height of the water stage corresponding to the mean discharge can only be determined by very difficult and extensive hydraulic measurements and calculations, in which considerable mistakes may easily be made, every experienced hydraulic engineer will agree with me that in such stretches of streams, in which the cross-section and the slope have remained unchanged, it may be concluded with complete justification and reliability, from a decrease in the mean of gauge readings taken during a long period, that their discharge has decreased.

Reply to C.—The supposition expressed by some of my opponents—that the discharge of rivers and streams has probably not decreased but that only their regimen has changed, since although at present that discharge at low and medium stages is smaller, yet it is very much greater at high stages, and that therefore the decrease in the former cases may be compensated by increase in the latter cases—is plainly incorrect, since on several rivers and at many gauge stations thereon the readings of high stages have decreased during the second period of observation. This has taken place on the Rhine at Basle, Worms, Bingen, and Cologne; on the Danube at Stein and Orsova; on the Vistula at Cracow; and on the Oder at Küstin. The supposition is further increased because in calculating the annual arithmetical mean of the gauge readings, the high-water stages are included, and because the monthly and annual mean of high-water stages have been found to decrease at almost all of the 51 stations on 13 rivers, which are compared in the tabular exhibit, and finally, because, if only a change in the regimen had taken place, the discharge during some months should decrease, and in the other months increase, a circumstance which has not taken place on any of the streams which are mentioned, except at a few gauge stations.

In my description of the circumstances attending the discharge of the Rhine at Emmerich and the Danube at Old Orsova I have already given the most striking proof that the decrease in low and medium stages is not compensated by that of the high stages which occasionally occur.

Reply to D.—The assertion made by Mr. Sasse, member of the board of public works, in his treatise upon the relations of the Elbe at Torgau,†

*Contributions to the hydrography of Bohemia, by A. R. Harlacher, Prague, 1872 and 1875.

†*Zeitschrift für Bauwesen* von Erbkam. Jahrgang, 1874. Journal of Architecture, Erbkam, 1874.

that no reliable conclusions can be reached that the discharge of streams has decreased until gauge readings have been taken during a period of at least 200 years could only be true if it were established that the years which are either very rich or very poor in water supply alternate and return at long intervals of about 40 or 50 years, for then it would be necessary at any rate to take at least two periods rich and two periods poor in water supply in order to obtain a reliable mean. But since it is apparent from the plotted gauge readings, in this as well as in my first treatise, of five rivers, during periods of from 60 to 142 years, that the periods rich or poor in water supply do not habitually last longer than from three to five years and that they do not recur in regular order, and since the further assumption of Mr. Sasse that the discharge of streams during years rich is frequently three times as great as that during years poor in water supply is true only of the smallest number of streams and only very seldom, of which my plotted gauge readings will convince any one, his assertion that in order to reach a reliable conclusion as to the decrease in the discharge of rivers gauge readings must be taken during a period of at least 200 years appears unfounded, since from my plotted gauge readings it appears that we can—if we take these during periods of from 40 to 60 years, divide them into two periods, calculate the mean of each of these, and then compare these means—infer from an increase or decrease in these that the discharge has become greater or less.

I should remark, however, that if in any year in either of the half periods of observation a flood, produced by extraordinary action of the elements, should occur, as happens rarely during 100 years, it would certainly seem advisable in order to obtain a correct mean of the gauge readings to exclude such an abnormal year and substitute for it the year of the other half period which was richest in water supply. I did not, however, deem it necessary to make the correction just referred to in my exhibit and plot of the gauge readings.

Reply to E.—The opinion of some of my opponents that a decrease in the discharge can only be reliably established by making direct measurements of it on rivers and streams from time to time during long periods, seems at first to be evident, but if we calmly consider the whole proceeding and the manner in which such measurements and calculations must be made, the surprising result will be reached that to establish the decrease in discharge by direct measurements is quite impracticable and almost impossible, as I now propose to show.

First of all, every hydraulic engineer will agree with me that it is an utter impossibility to make during 30 or 40 years uninterrupted measures of discharge, and at the varying stages at such stretches of streams in which the current, the cross-section, or the slope are constantly changing, and then by comparing the volumes of discharge of the two periods to determine whether an increase or decrease has taken place. In this matter every experienced hydraulic engineer will agree with me that the discharge can only be measured on those stretches of the stream in which the current, cross-section, and slope have remained unchanged during 30 or 40 years, as I have shown to be the case on the Rhine at Basle and on the Danube at Old Orsova.

Now, if we assume that, in order to decide the question whether the discharge of a stream has increased or diminished, a hydraulic engineer is intrusted with measuring it on an unchanging stretch of it during a *period of* 30 years, and assuming also, for the sake of simplicity, that in *this stretch only those* stages occur—that is, the lowest h, the medium h^1, *and the high* h^2—*and* that he has in the first year executed his trust,

and has found by accurate measurements that at the selected cross-section of the stream the discharge per second at the stage h was M, at the stage h^1 was M^1, and at the stage h^2 was M^2.

Now, if the engineer, after 5, 10, 20, or 30 years have elapsed, makes similar accurate measurements of discharge at the same cross-section at the same three different stages, it is evident that, if the current, cross-section, and slope of the stream have remained entirely unchanged, he will find exactly the same quantities of discharge, M, M^1, and M^2, and it will be impossible, in spite of these measurements, after a lapse of 30 years, to determine whether there has been an increase or decrease in the volume of discharge, since the gross amount of the latter depends upon the duration of the low, medium, and high water stages.

What has just been said concerning the three stages of the water is also true of all the variable stages of a stream during the whole period of observation, and therefore my assertion that the volume of discharge of a stream cannot be determined by measurements at an invariable cross-section, when the discharge will during the whole period of observation be the same for the same stage of water, but only from the calculated mean of the gauge readings whether the volume of discharge has increased or decreased, seems well founded.

If it is desired, however, to calculate and compare with each other the gross volume of discharge which takes place during two periods of about fifteen or twenty years each, the following method, already adopted by Mr. Grebenau in calculating the gross volume of discharge of the Rhine at Sondernheim from 1840 to 1867, and by Mr. Sasse, member of the board of public works in his calculation of the gross volume of discharge of the Elbe at Torgan * from 1831 to 1850, must be pursued.

First of all the curve must be constructed based upon accurate measurements at various stages, and at a constant cross-section, from which the discharge at any stage can readily be obtained for a second of time. Then from the table of gauge readings the exact number of days of the period during which each stage lasted, and then multiplying the discharge $M\ M_1M_2$, &c., per second at each stage by $60'' \times 60' \times 24 = 86{,}400$ seconds, and this product by the number of days of each half period of fifteen or twenty years, during which the stage lasted, and adding together all of these sums for each of the two periods, we can learn from the resulting gross amounts whether in the second half of the period of observation the discharge has decreased.

Now every experienced hydraulic engineer must agree with me that it is very difficult to measure the discharge of a large stream at the different and especially at the high stages, also to obtain the correct curve from these, and also to make the weary, time-robbing, and tiresome collection of the same stages from the tables of gauge readings taken during a long period, and to make the unavoidable rounding off of those that are nearly alike to get them into designated groups, and finally to perform the similar time-consuming multiplication and addition of colossal sums, in consequence of which a very busy engineer must intrust the labor to an assistant, and that mistakes are very easily made which may be greater than the actual difference between the gross amounts of discharge of the two half periods of observation, and actually reverse the result, and that on the contrary the calculation of the annual mean stage of the river, as well as the mean of the gauge readings taken dur-

*Zeitschrift für Bauwesen von Erbkam, vom Jahr 1874. Journal of Architecture, by Erbkam, 1874.

ing a long period of time, can be made easily and without error from the tables of gauge readings.

Under these circumstances hydraulic engineers will probably now acknowledge that the result of Grebenau's experience in the measurements and calculations of discharge so numerously made by him, that the arithmetical mean for a long period, calculated from the tables of gauge readings, is nearly identical with that stage of the river which corresponds to the mean of the discharge obtained from measuring the volume of discharge during that period, is highly important, and it is therefore easier and more reliable to obtain the mean stage of a river during a long period from the tables of the gauge readings taken during that period.

Now I will mention another simple method by which, without the very difficult and time-consuming measurements of discharge, even a non-professional can calculate the amount of decrease in the discharge of a stream during a certain period. It must be here remarked that only such stretches and such gauge stations, where the current, cross-section, and slope of the stream have remained unchanged during the whole period of observation, are suitable for reliable calculations of the actual decrease in discharge, and I will therefore, to illustrate my method by examples, take the stations on the Rhine at Basle and on the Danube at Orsova, both of which are fully suited thereto.

According to the comparison of the gauge readings in the annexed tabular exhibit in No. 1, the annual mean stage of the Rhine at Basle decreased on an average during the second half of the period of observation from 1809 to 1868 (that is, from 1839 to 1868) at the rate of .114 inch per annum; that is, an upper layer of water .114 inch thick was discharged less each year. Mr. Grebenau, it is true, did not give the mean of the annual stage from 1839 to 1868, but it will probably be very nearly the same as that for the period from 1840 to 1872 given in No. 2 as 5.8495 feet, or 5 feet 10.194 inches above zero. If now the mean surface velocity for this stage is obtained, which can easily be done by throwing a number of floats into the stream at equal distances apart, we can, by multiplying the breadth of the stream by the mean surface velocity and the product by the established sinking in the height of the water surface, *i. e.*, .114 inch, obtain the volume of water per second by which the discharge of the Rhine at Basle is decreased. All the data necessary in order to make the calculations for this case can be obtained from the "Internationalen Rheinstrom-Messung bei Basel im November 1867."* It will be found from this scientific and very thorough work that at the stage 5′ 10.194″ above the zero of the water at Basle the width of the water surface is 728.31762′, and the mean velocity of the water on the surface of the stream is 7.4144′, so that the decrease in the volume of discharge will be $728.31762' \times 7.4144' \ .00952 = 46.7971$ cubic feet per second, and by further multiplication will amount to 1,475,794,557 cubic feet per annum.

Now, as the area of the whole valley of the Rhine above Basle is given in the Swiss charts at 35,906,900,000 square meters = 386,468,047,300 square feet, the foregoing decrease in the discharge of the Rhine would indicate a decrease in the depth of the rainfall of $\frac{1,475,794,557}{386,468,047,300} = .0038' = .0456''$ per annum.

Now, if we base our calculations upon the decrease in the height of

*International measurements of the Rhine at Basle in November, 1867. These measurements of the Rhine were described and published by Grebenau. March, 1873. Lindauer's bookstore.

water-stages during the period of 16 years from 1857 to 1872, which, under the head of No. 2 in the tabular exhibit, is shown to be .77556′′= .06463′, and take the corresponding dimensions from the work above cited, *i. e.*, the stage at 5.3344′, the width at 659′, and the mean velocity at 6.56′, the decrease of the water during the period will be found to be 659′ × 6.56′ × .06463′=279.5703 cubic feet per second and 8,816,528,981 cubic feet per annum. The amount of decrease in the depth of rainfall per annum would therefore be $\frac{8,816,528,981}{386,468,047,300}$=.0228′=.2736′′.

It will be shown hereafter how nearly these calculated results agree with the meteorological observations.

During the second half of the period of 36 years, *i. e.*, from 1858 to 1875, the mean stage of the Danube at Old Orsova was 8.2116′ and the average decrease of the latter .0748′, as will be seen at No. 34 of the tabular exhibit.

According to the cross-section of the Danube at Old Orsova, taken in 1873 by Sir Wawra, chief of the board of public works, and shown on Sheet 6, the width of the stream when at this stage was 1,549′, and the mean surface velocity, taken, however, at a stage only 3.28071′ above zero, was 2,687′.

It is universally known that the mean surface velocity of a stream increases with its height, and hence I ascertained by actual measurements of the velocity of the Danube at different stages between Ofen and Pesth, and at a similar cross-section at the foot of Block's hill, that when the water rises 4.92′ then the mean velocity of the surface current is increased about 1.148′. It can therefore be assumed approximately that when the Danube at Old Orsova is at its 8.2116′ stage its mean surface velocity will be 2.687′ + 1.148′=3.835′.

The decrease in the discharge for an annual diminution of .0748′ in the height of the stage would therefore be 1.549′ × 3.835′ × .0748′= 43.2189 cubic feet per second, and consequently 1,362,951,220 cubic feet per annum.

The whole valley of the Danube has an area of 14,420 geographical square miles, of which the portion below Orsova contains 4,100. The portion above this place then contains 10,320 geographical square miles =6,093,561,254,602 square feet. The decrease in rainfall is therefore found to be $\frac{1,362,951,220}{6,093,561,254,602}$=.000224′=.0027′′ per annum, and therefore during the whole period of 18 years, .0486 inch. It is no doubt self-evident that this decrease in rainfall was greatest in the mountainous regions and on the contrary less on the plains.

Reply to F.—In order to remove the doubts and exceptions in regard to the correctness of the assertion made by me that the rainfall has been decreased by the destruction and devastation of extensive forests, I believe it to be necessary, in the first place, to call attention to the opinions and treatises on this subject by distinguished experts and naturalists given in detail in Chapter I, and then to communicate the following explanations and results of my observations.

It is quite natural that the meteorological observations made in England, Scotland, and at Paris, St. Petersburg, and Copenhagen, during about 100 to 190 years, did not indicate any decrease in the volume of the annual rainfall, since these countries and cities are situated in the vicinity of the sea, and receive the rain-clouds, so to speak, from first hands. *Even if it should* appear from the meteorological observations *at the principal cities of* the continent that at these no decrease of rainfall *had taken place, this* can be explained by the fact that during the

last decades no such extensive clearings as would cause a decrease in the volume of rainfall have taken place in their vicinities.

I can give only two instances to prove that there has been a decrease in rainfall in those regions, and especially those of a mountainous character, in which large clearings were made, because, unfortunately, in former times no meteorological stations existed in these localities.

Mr. Adam Seidel, chief forester at Bodenbach, in the Erz* Mountains of Bohemia, made precise meteorological observations uninterruptedly during the period from 1828 to 1873, the results from which were revised and published by the Imperial Royal Central Bureau of Meteorology. If the observations of 1828 and 1850, which were incompletely made, are eliminated, and then divide the remainder of the time into two equal periods of 22 years each, and calculate their arithmetical means, the following results will be obtained, viz:

Meteorological observations by Chief Forester Adam Seidel, at Bodenbach; arranged by Stanislaus Kostliwy.

	Annual mean.		Decrease from 1852 to 1873.
	1829 to 1851.	1852 to 1873.	
Mean temperature of the air ..... degrees Fahrenheit..	47. 66	47. 22	0. 44
Pressure of vapor ..... inches..	0. 2992	0. 2874	0. 0118
Humidity of the air ..... per cent..	84. 6	82. 1	2. 5
Number of days of rain	158	145. 8	12. 2
Depth of rainfall ..... inches..	25. 235	23. 976	1. 259

These results substantiated the fact that in the mountainous regions at Bodenbach a decrease in the pressure of the vapor, relative dampness of the air, the number of days of rain, and the depth of rainfall has taken place in the latter period of 22 years.

The annual decrease in the depth of rainfall amounted to $\frac{1.259}{22} = 0.057$ inch.

Mr. Plantamour, the director of the meteorological observatory at Geneva, also has shown that a decrease of rainfall has taken place in the Alps. He found, namely, in the latter period of 14 years, from 1861 to 1874, in comparison with the preceding period of 20 years, on the St. Bernard, at a height of 8,116.5 feet, an increase of temperature of 0.72° F., a decrease in rainfall of .008 inch, and in snowfall of about one-half, *i. e.*, from 32.8 to 15.93 feet. For Geneva a comparison of the last 11 years with the preceding period of 35 years shows an increase in temperature of 1.134° F., and a decrease in the rainfall of 3.3 inches, and therefore an annual decrease of $\frac{3.3}{11} = .3$ inch. These changes, according to the opinion of Plantamour, are due to the contraction or decrease in the size of the glaciers which has been observed during the last 12 years.

Now, as we found in the preceding paragraph, in my reply to E, from the decrease in the height of water stages, that there was an average annual decrease in the depth of rainfall in the valley of the Rhine above Basle during the period from 1839 to 1868 of .0456″ and during the period of 16 years from 1857 to 1872 of .2736″, the similarity of these results, obtained from an entirely different source, to the decrease of *rain*fall in the mountainous regions at Bodenbach and Geneva is *surprising.*

* Ore.

Several countries in Europe have, unfortunately however, only since the last few years established meteorological stations in the forest and mountain regions, and after the lapse of several decades it is highly probable that they will show the same decrease in rainfall as at Bodenbach and Geneva.

CONCLUSION.

As I now believe that I may assume that my theory in regard to the decrease of water in springs and rivers, announced in 1873, has been established as a fixed fact by my discussion, and then by the tabular exhibit of observations at 56 stations on 13 rivers, and finally by the abundant opinions and thorough treatises of naturalists and experts given by me, I take the liberty of making the most earnest request of my readers and colleagues that each may labor in his own sphere, so that the higher governments, authorities, corporations, land-owners, and communities may finally be convinced of the numberless disadvantages and dangers our present cultivated countries are approaching, if a limit is not set to the further devastation and destruction of forests, and that it is imperatively necessary to carry out, as rapidly as possible, the precautions and measures recommended in my treatise of 1873, and which have been also warmly approved by other authorities, and thus prevent, as far as it yet lies in man's field of labor, the calamity of a still further decrease of the water in springs and rivers which threatens future generations.

Finally, I take the liberty of saying to my esteemed readers that I am ready to furnish cheerfully all the data and results which I have collected, and all the books and pamphlets which have been published bearing upon this subject, for the examination and use of all such gentlemen who intend to still more thoroughly investigate this hydraulic question.

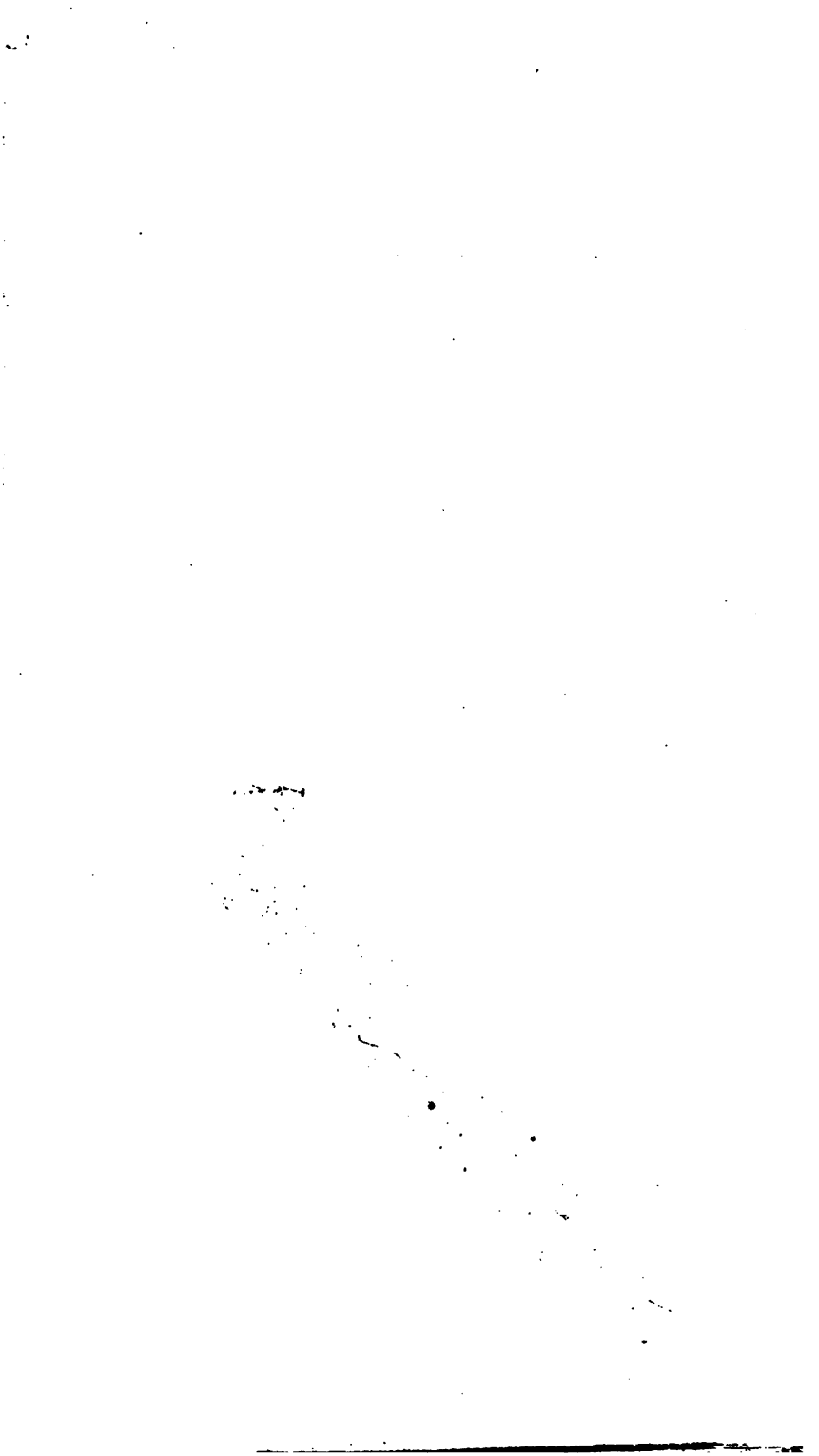
[Note by the translator.]

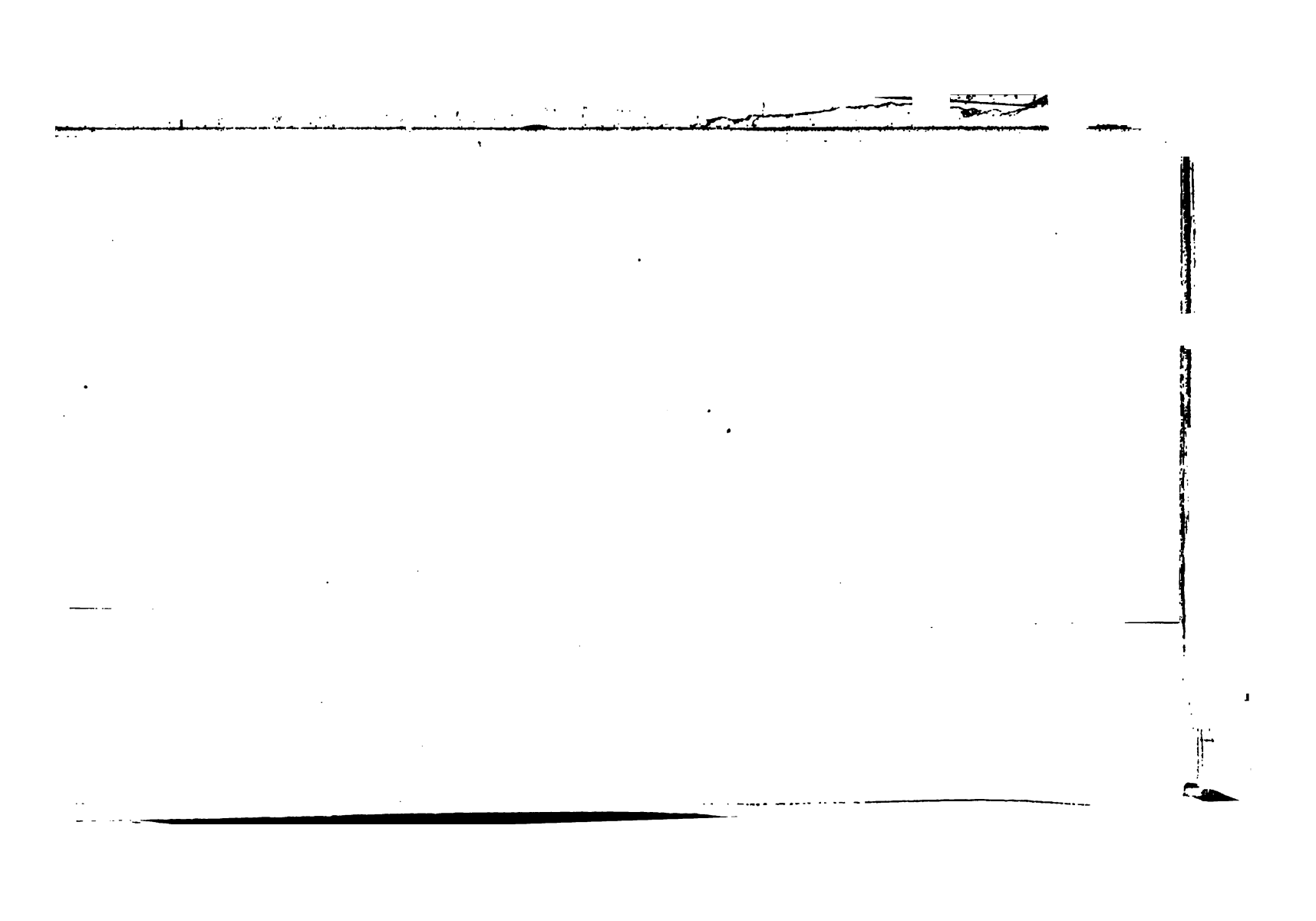
In making the foregoing translation, I have attempted to make it as literal as possible, and yet make it fairly intelligible English reading.

I have used the word "rainfall" to indicate that term of the author which literally translated would be "aqueous atmospheric precipitations," and which includes rain, snow, hail, dew, &c.

I have also changed all the metric measures and centrigrades into American measures and degrees of Fahrenheit.

G. WEITZEL,
Major of Engineers,
Brevet Major-General, U. S. A.





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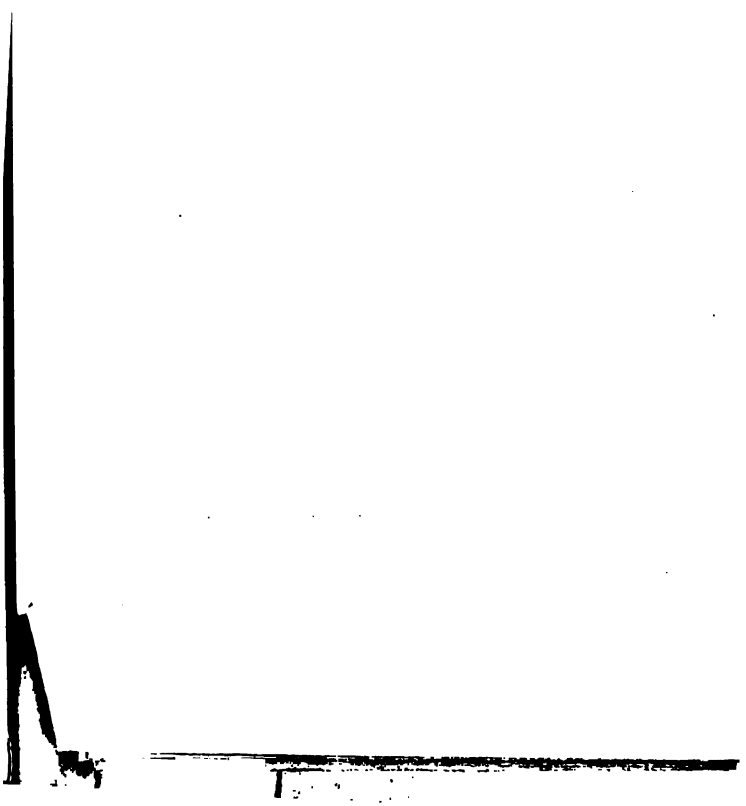
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